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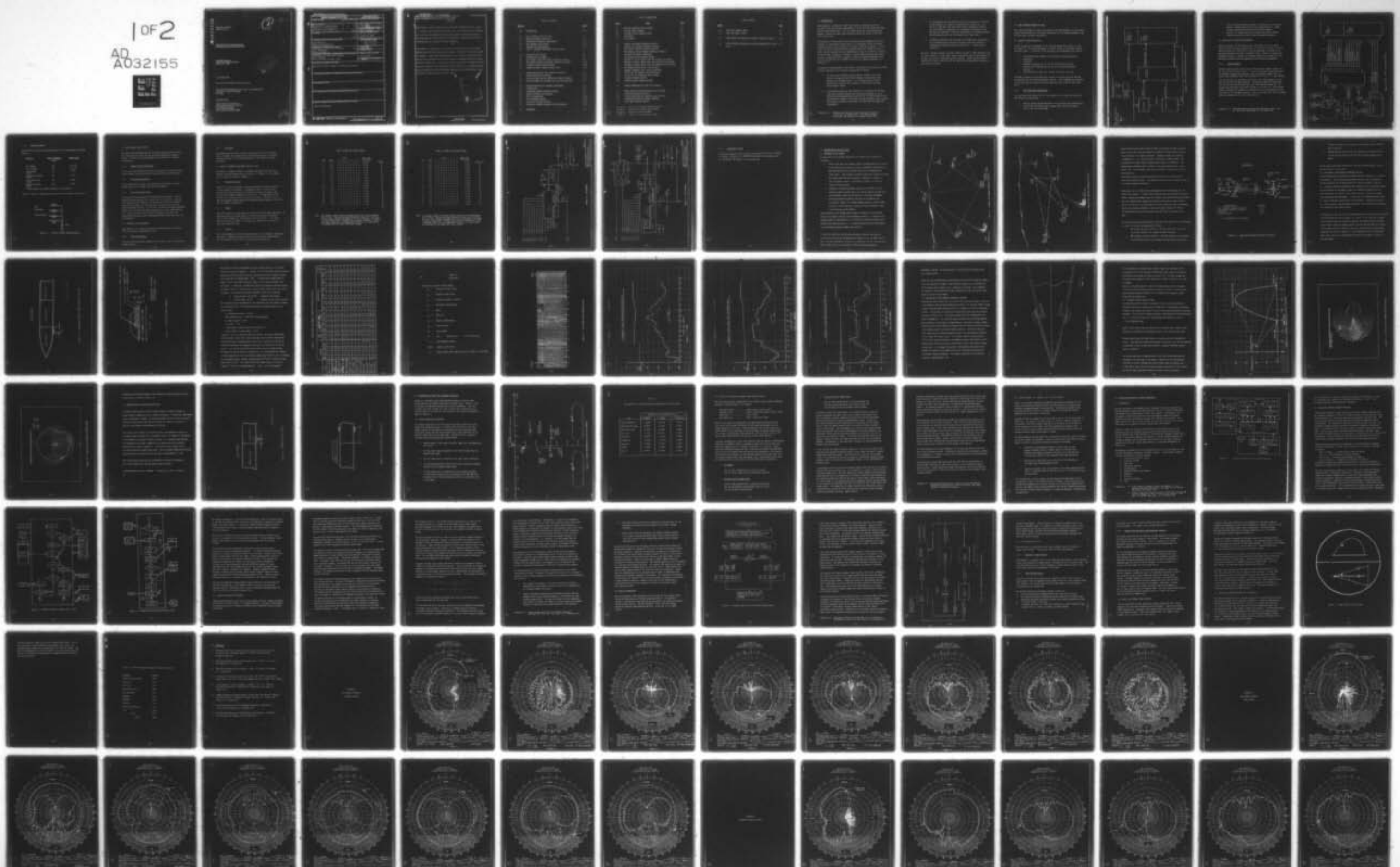

TECHNICAL REPORT
(IBM 76-L61-017)

DME SURFACE TO SURFACE MISSILE DEMONSTRATION SYSTEM ANALYSIS

IBM CORPORATION
FEDERAL SYSTEMS DIVISION
OWEGO, NY 13827

31 OCTOBER 1976

Approved for public release; distribution unlimited.

FINAL REPORT FOR PERIOD 1 JULY 1976 -- 31 OCTOBER 1976
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PREPARED FOR:

Guidance and Control Directorate
US Army Missile Research, Development
and Engineering Laboratory
US Army Missile Command
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ABSTRACT

System design, analysis and tests were performed in preparation for a joint U.S. Army/Air Force demonstration flight test. This flight test will involve use of the Air Force Advanced Location and Strikes System (ALSS) Distance Measuring Equipment (DME) navigation and guidance techniques for control of a Hawk missile on a surface-to-surface trajectory.

Requirements are defined for the interface between the DME Weapon Guidance Subsystem and the Hawk flight control system. A DME data link antenna system was designed. Scale model antenna pattern test results are presented which validate the performance for the DME, Telemetry and Command Destruct antennas needed for flight tests. A projected flight test geometry is defined relating the missile trajectory and ALSS ground station locations. Functional requirements are identified for modifications necessary to the ALSS software to provide missile control during the flight tests.

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1.0 INTRODUCTION

IBM Corporation is pleased to submit this report in compliance with Data Item 001 of the Contract Data Requirements List for Contract DAAH01-76-A-0024 Delivery Order Number 0003. This is a final report for system engineering analysis, design, and test efforts conducted during the period 13 May 1976, to 30 October 1976.

The objective of these efforts was to establish system implementation details pertinent to demonstration flight tests, in a subsequent follow on program, of DME control of a Hawk missile on a surface to surface trajectory. In this report the efforts during the above reporting period are called the Phase I study, and the expected follow-on demonstration flight test effort is referred to as the Phase II Program. The Phase I efforts reported herein were accomplished in conjunction with a parallel study which supported DME/Hawk simulation and guidance analysis at MICOM, and which are reported separately in Reference 1-1.

The specific accomplishments of the Phase I study fulfill the objectives of the contract statement of work and may be summarized as follows:

1. The electrical, mechanical and procedural interfaces have been defined to integrate the DME WGSS (Weapon Guidance Control Subsystem) into the Hawk vehicle. This includes design of WGSS modifications necessary for compatible interface with the Hawk flight control system.

2. A DME antenna system has been defined for installation on the Hawk. Scale model antenna pattern tests have been performed to; (1) establish the preferred mounting locations for this DME antenna system and predefined Telemetry and Command Destruct antennas, and (2) verify that pattern coverage is consistent with demonstration flight test requirements.

Reference 1-1: "DME-Basic Hawk Missile Study-Final Report for period 1 July 1976 - 30 October 1976," IBM Report Number F18-76-H02, IBM, Huntsville, Alabama, October 1976

3. An investigation has been made of practical constraints on ALSS-DME system operations to support the demonstration flight test. The results of DME data link line-of-site tests, conducted at WSMR by Air Force ASD-Det 1 personnel, were evaluated in conjunction with DME accuracy tradeoffs to define a recommended site location geometry and DME operating mode for the demonstration flight tests.

4. Preliminary definition has been made of the functional requirements for the modifications which must be made to the ALSS software to implement the DME/Hawk Surface-to-Surface Missile (SSM) guidance techniques.

Sections 2 through 5 present the major results for each of these different areas of study. However, in some cases, interim engineering reports were prepared to document the results of detailed specific analysis. These separate analysis reports are listed in Section 6 and are identified by appropriate references in the different sections.

2.0 WGSS INTERFACE DESIGN AND TEST

This section provides an overall description of the DME equipment to be installed onboard the Hawk Missile, functional requirements for the onboard equipment, and the subsystems interface requirements.

2.1 ONBOARD SYSTEM DESCRIPTION

A block diagram of the equipment to be installed onboard the missile is shown in Figure 2-1. The onboard equipment is denoted herein as the Weapon Guidance Subsystem (WGSS). It consists of the following Line Replaceable Units (LRU's).

- Receiver/Processor (modified for the Hawk missile application)
- Transmitter
- Circulator
- Antennas (1 antenna will be used for Ground DME controlled vehicles and 2 antennas will be used for Airborne Controlled Vehicles)
- Antenna Summing Network (for airborne controlled vehicles)

The WGSS interfaces with the DME relay stations via the RF data link for DME measurements and for receiving guidance commands. These commands are processed by the WGSS where the signals are conditioned and sent to the missile's autopilot.

2.1.1 WGSS Functional Requirements

The functional requirements for the DME equipment to be installed onboard the Hawk Missile are as follows:

- Receive, detect and perform checks on pulse coded link transmissions.
- Provide DME transponder reply messages when dictated by control bits in the received message.

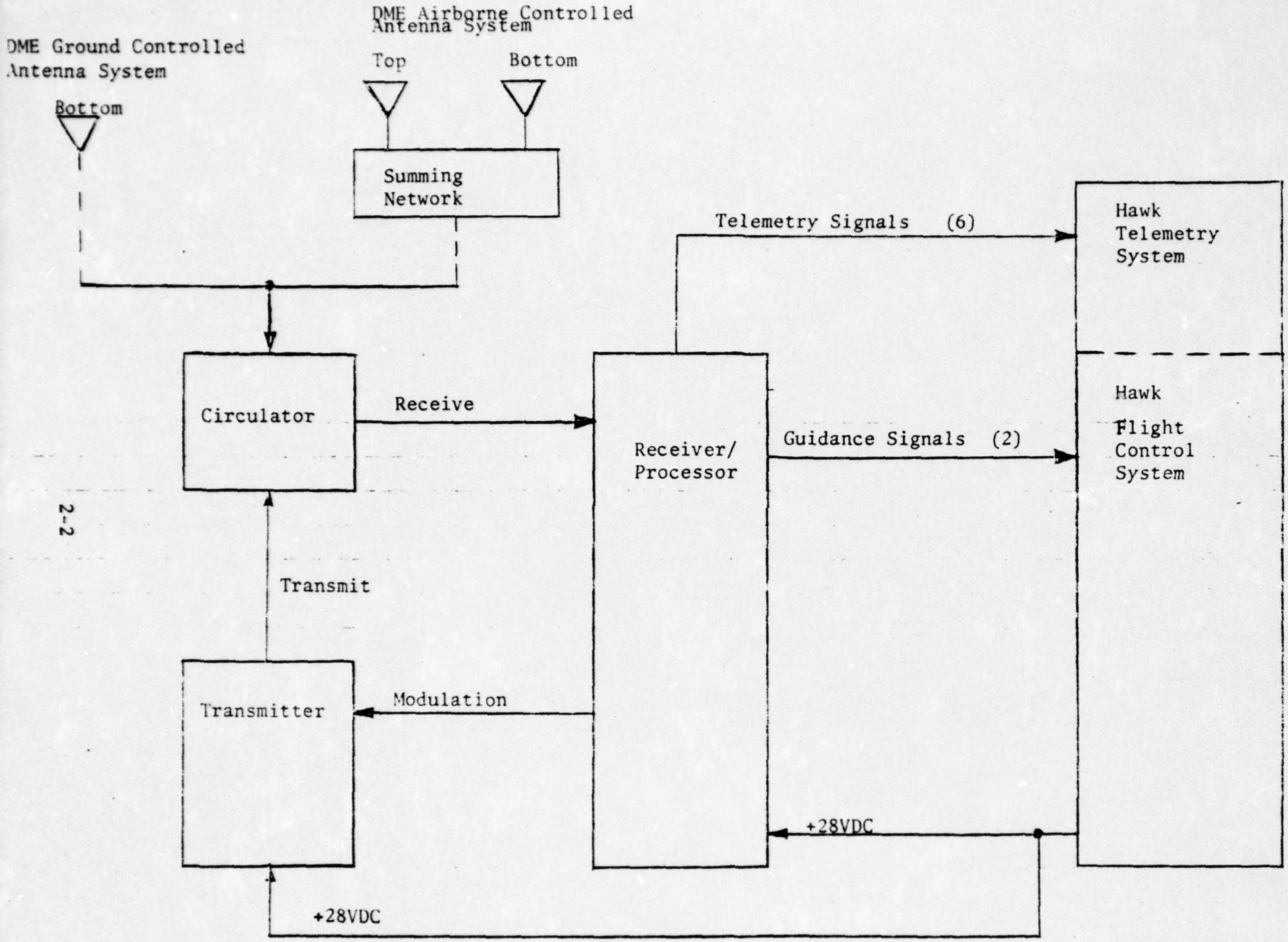


Figure 2-1 WGSS - SSM Functional Block Diagram

- Store two decoded guidance messages in digital form, and provide digital to analog conversion to yield proportional D.C. output voltages representing yaw and pitch guidance commands.
- Provide D.C. output signals for telemetry monitoring of WGSS functions pertinent to post flight performance evaluation.

2.2 WGSS/MISSILE INTERFACE REQUIREMENTS

Onboard interfaces for the Hawk missile system shall consist of control signals between the vehicle-mounted WGSS and the Hawk's autopilot subsystem, electrical power from the missile to the DME equipment and signals to be monitored through the missile's telemetry system. Figures 2-2 depicts the WGSS/Hawk interface. Reference 2-1 presents detailed requirements for the WGSS/Hawk interface which are summarized in the following paragraphs.

2.2.1 Control Signals

The WGSS subsystem shall provide two ±10 VDC guidance command signals, one for yaw and one for pitch control. The positive guidance signal shall have 127 descrete voltage steps from null, with the maximum command (all "1s" except sign) producing a full scale voltage of +10 volts D. C. This maximum positive voltage will represent a pitch up or turn right command of 8.17g (263 ft/sec^2) for the Hawk autopilot. The negative guidance signal shall have 128 discrete voltage steps from null, with maximum command (all "0s" except sign) producing a full scale voltage of -10 volts D.C. This maximum negative voltage will represent a pitch down or turn left command of 8.17g (263 ft/sec^2) for the Hawk autopilot. With a null input (all "0s") the output guidance command shall be zero ±.039 volts D.C.

Reference 2-1: "WGSS-SSM Subsystem Design and Performance Goals," IBM No. 76-L61-018, IBM, Owego, NY, 15 October 1976

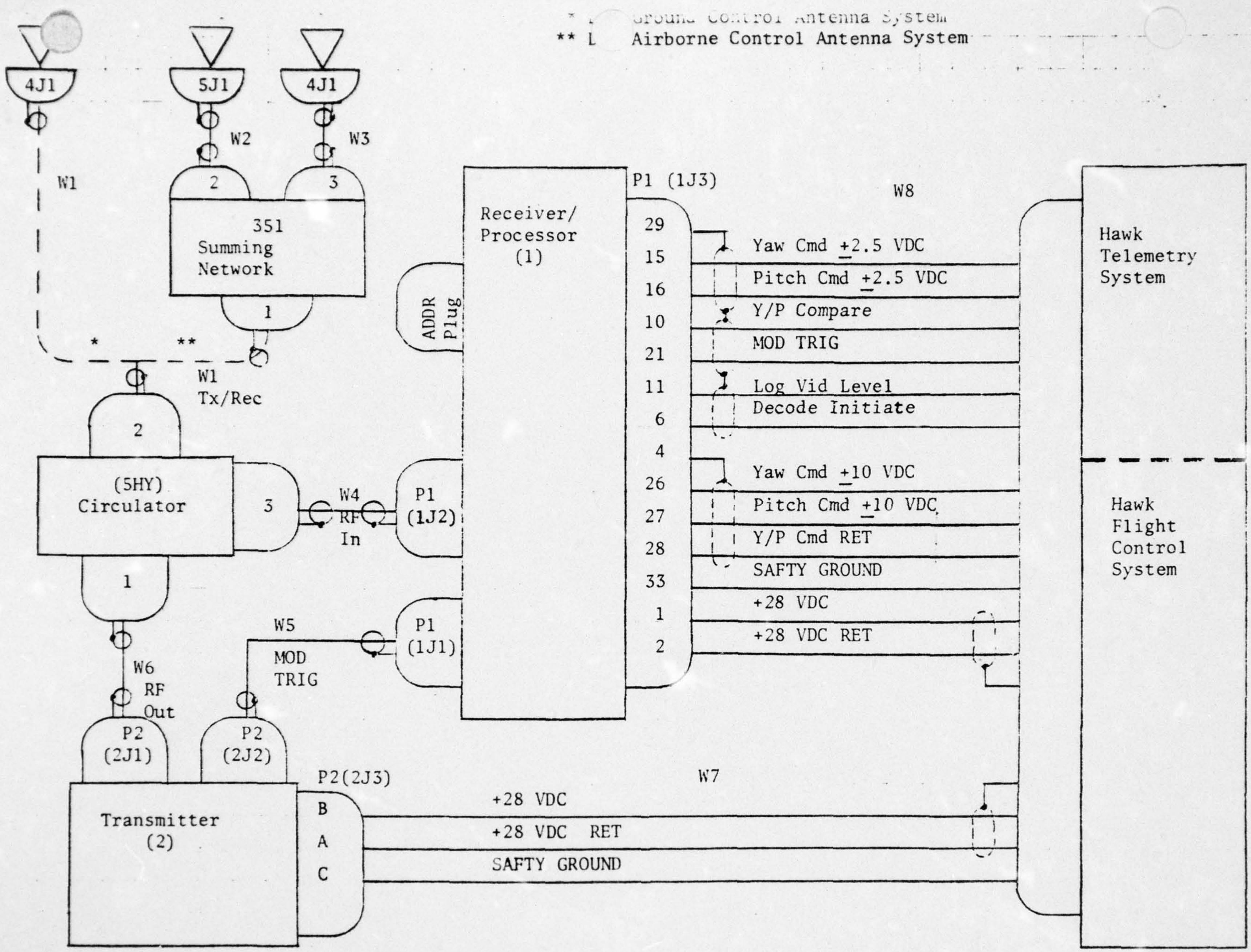


Figure 2-2 WGSS - SSM Wiring Diagram (Sheet 1)

2.2.2 Telemetry Signals

The WGSS shall provide the following signals to be telemetered by the Hawk missile.

Function	Source Impedance (ohms)	Signal Type
Yaw Command	750	±2.5 VDC
Pitch Command	750	±2.5 VDC
*Y/P Compare (200K)	750	+5 VDC
*Modulation Trigger (400K)	750	+5 VDC
*Log Video Level (100K)	750	+5 VDC
*Decode Inititate (800K)	750	+5 VDC

* These signals are summed internally in the TM unit.

Figure 2-3 shows the summing network that must be provided in the TM Unit.

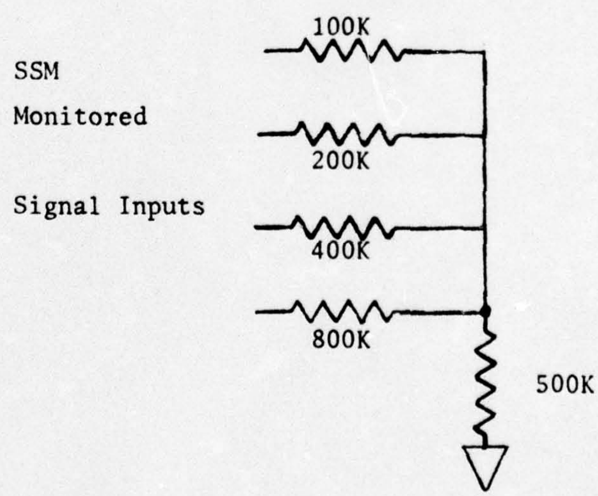


Figure 2-3 Telemetry Signal Summing Network

2.3 DME HARDWARE DESIGN STATUS

The present WGSS configuration has to undergo modifications to provide the required signal levels for Yaw and Pitch command and telemetry signals. To meet altitude requirements the circulator will require encapsulation.

2.3.1 Command Signal Modification

The yaw and pitch command signals must be modified to produce a ±10 VDC output command signal looking into a nominal 120K ohm load impedance.

2.3.2 TM Signal Modification

The yaw and pitch TM signals must be modified to produce a ±2.5 VDC output signal with a nominal 750K ohm load impedance.

2.3.3 Circulator Modifications

The present WGSS was designed for operation below 50K feet. The SSM program requires hardware to be operational up to 80K feet. Lab tests have shown that the circulators in the old style WGSS to be used for demonstration flight test can break down (arcing) at less than the required maximum altitude. To solve this circulator altitude environment problem the circulator and cables connecting to it were encapsulated in RTV. Tests were then run in the lab which demonstrated that the encapsulated circulator would withstand altitudes of 90K feet with 8 KW being applied.

2.4 HARDWARE TEST REQUIREMENTS

Upon completion of hardware modifications the WGSS shall be tested to verify that design requirements are met.

2.4.1 Receiver/Processor

The Yaw and Pitch guidance commands and TM signals shall be verified for proper operation.

2.4.2 Circulator

The encapsulated circulator shall be tested along with its associated cables, antenna's and summing network for proper operation at required altitude, 80K feet, with 8 KW being applied to the input port of the circulator.

2.5 PHASE II HARDWARE DEVELOPMENT AND TEST PLANS

Following is a summary of Phase II hardware development and Test Plans. Hardware design and modification will start on 1 October 76, and hardware will be ready for shipment 1 January 77.

2.5.1 Receiver/Processor

Figures 2-4 and 2-5 are marked up drawings showing the changes necessary for the Yaw and Pitch channels. The adding of the 5.1K resistor and changing the values of R13, R14, R19 and R20 increase the range of the Yaw and Pitch guidance commands to ±10 volts DC. The adjustement of R14 and R20 pot will provide the ±2.5 volt DC TM signal. Tables 2-1 and 2-2 show the expected voltage outputs for different digital inputs for the pitch and yaw commands respectively.

2.5.2 Cables

IBM shall provide all cable connectors associated with the WGSS subsystems. MICOM shall make the signal cable to the receiver processor and power cable to the transmitter. IBM shall provide all RF cables. All cables shall be installed by MICOM. At present, all connectors are on order or have been received by IBM.

2.5.3 Antennas

Full scale antennas for both DME configurations will be designed, fabricated and tested. Performance characteristics and installation considerations for these antennas are discussed in the following section 3.0.

Table 2-2 WGSS YAW Channel Output

TEST	WORD	BITS 1	2	3	4	5	6	7	8	P	Volts (DC) (See Note)	
1	6,7	1	0	0	0	0	0	0	0	0	10.000	±.039V
2	6,7	0	0	0	0	0	0	0	0	1	0.000	
3	6,7	0	0	0	0	0	0	0	1	0	0.078	
4	6,7	0	0	0	0	0	0	1	0	0	0.156	
5	6,7	0	0	0	0	0	1	0	0	0	0.313	
6	6,7	0	0	0	0	1	0	0	0	0	0.625	
7	6,7	0	0	0	1	0	0	0	0	0	1.250	
8	6,7	0	0	1	0	0	0	0	0	0	2.500	
9	6,7	0	1	0	0	0	0	0	0	0	5.000	
10	6,7	0	1	1	1	1	1	1	1	0	10.000	
11	6,7	1	1	1	1	1	1	1	1	1	-0.078	
12	6,7	1	1	1	1	1	1	1	0	0	-0.156	
13	6,7	1	1	1	1	1	1	0	0	1	-0.313	
14	6,7	1	1	1	1	1	0	0	0	0	-0.625	
15	6,7	1	1	1	1	0	0	0	0	1	-1.250	
16	6,7	1	1	1	0	0	0	0	0	0	-2.500	
17	6,7	1	1	0	0	0	0	0	0	1	-5.000	

NOTE: The output voltages listed are nominal values for room temperature ($25^{\circ} \pm 10^{\circ}C$). Over the required temperature range (-54° to $+71^{\circ}C$) the full scale voltage may change by ±0.3 volts causing a ±3% change in output scale factor. However, the linearity tolerance of ±.039 volts shall apply over all temperatures relative to a scale factor as determined by the actual full scale voltage.

Table 2-1 WGSS Pitch Channel Output

Test	Word	BITS 1	2	3	4	5	6	7	8	P	Volts (DC) (See Note)	
1	4,5	1	0	0	0	0	0	0	0	0	-10.000	±.039 volts
2	4,5	0	0	0	0	0	0	0	0	1	0.000	
3	4,5	0	0	0	0	0	0	0	1	0	0.078	
4	4,5	0	0	0	0	0	0	1	0	0	0.156	
5	4,5	0	0	0	0	0	1	0	0	0	0.313	
6	4,5	0	0	0	0	1	0	0	0	0	0.625	
7	4,5	0	0	0	1	0	0	0	0	0	1.250	
8	4,5	0	0	1	0	0	0	0	0	0	2.500	
9	4,5	0	1	0	0	0	0	0	0	0	5.000	
10	4,5	0	1	1	1	1	1	1	1	0	10.000	
11	4,5	1	1	1	1	1	1	1	1	1	- 0.078	
12	4,5	1	1	1	1	1	1	1	0	0	- 0.156	
13	4,5	1	1	1	1	1	1	0	0	1	- 0.313	
14	4,5	1	1	1	1	1	0	0	0	0	- 0.625	
15	4,5	1	1	1	1	0	0	0	0	1	- 1.250	
16	4,5	1	1	1	0	0	0	0	0	0	- 2.500	
17	4,5	1	1	0	0	0	0	0	0	1	- 5.000	

NOTE: The output voltages listed are nominal values for room temperature ($25^{\circ} \pm 10^{\circ}$C). Over the required temperature range (-54° to $+71^{\circ}$C) the full scale voltage may change by ±0.3 volts causing a ±3% change in output scale factor. However, the linearity tolerance of ±.039 volts shall apply over all temperatures relative to a scale factor as determined by the actual full scale voltage.

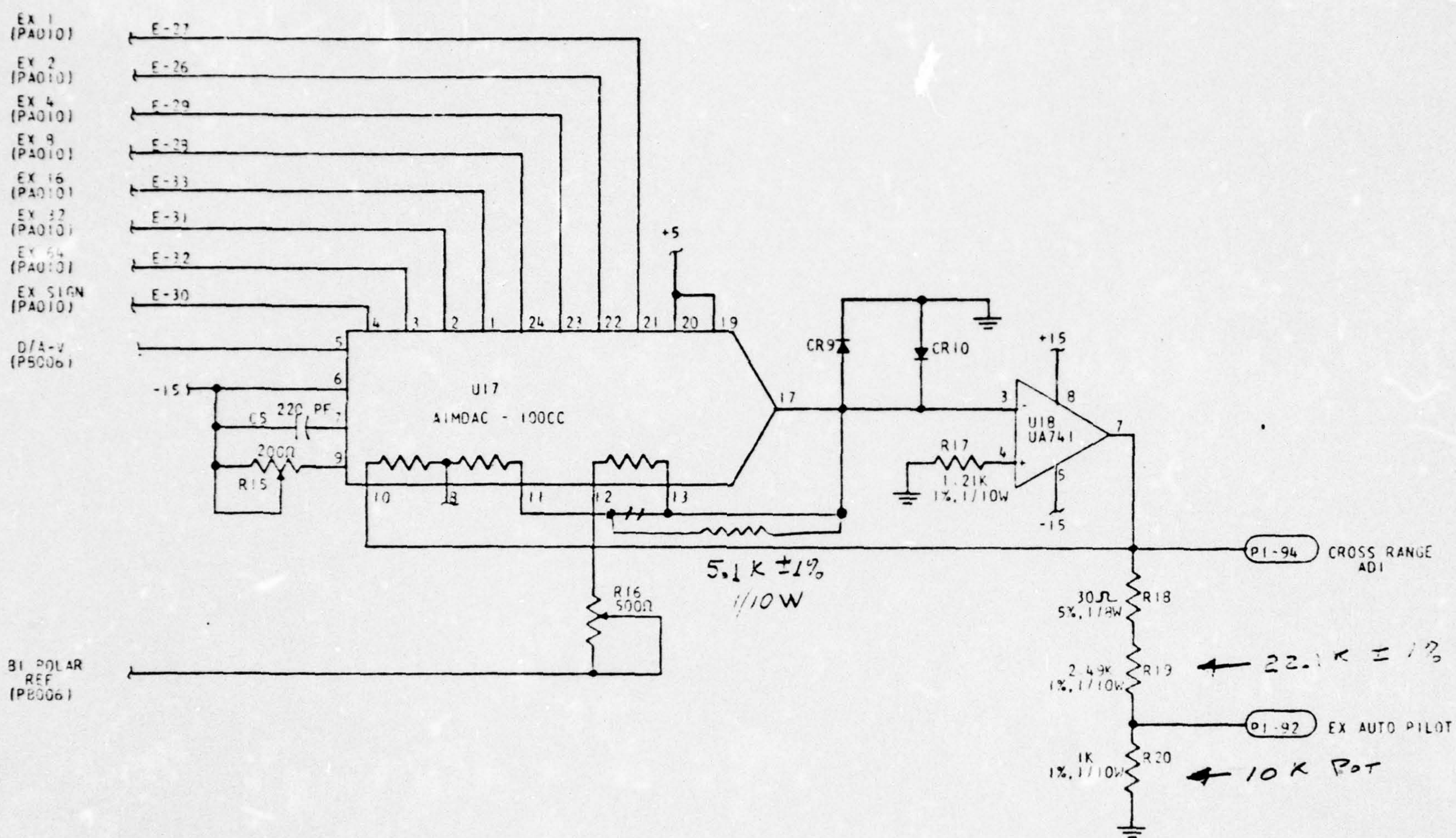
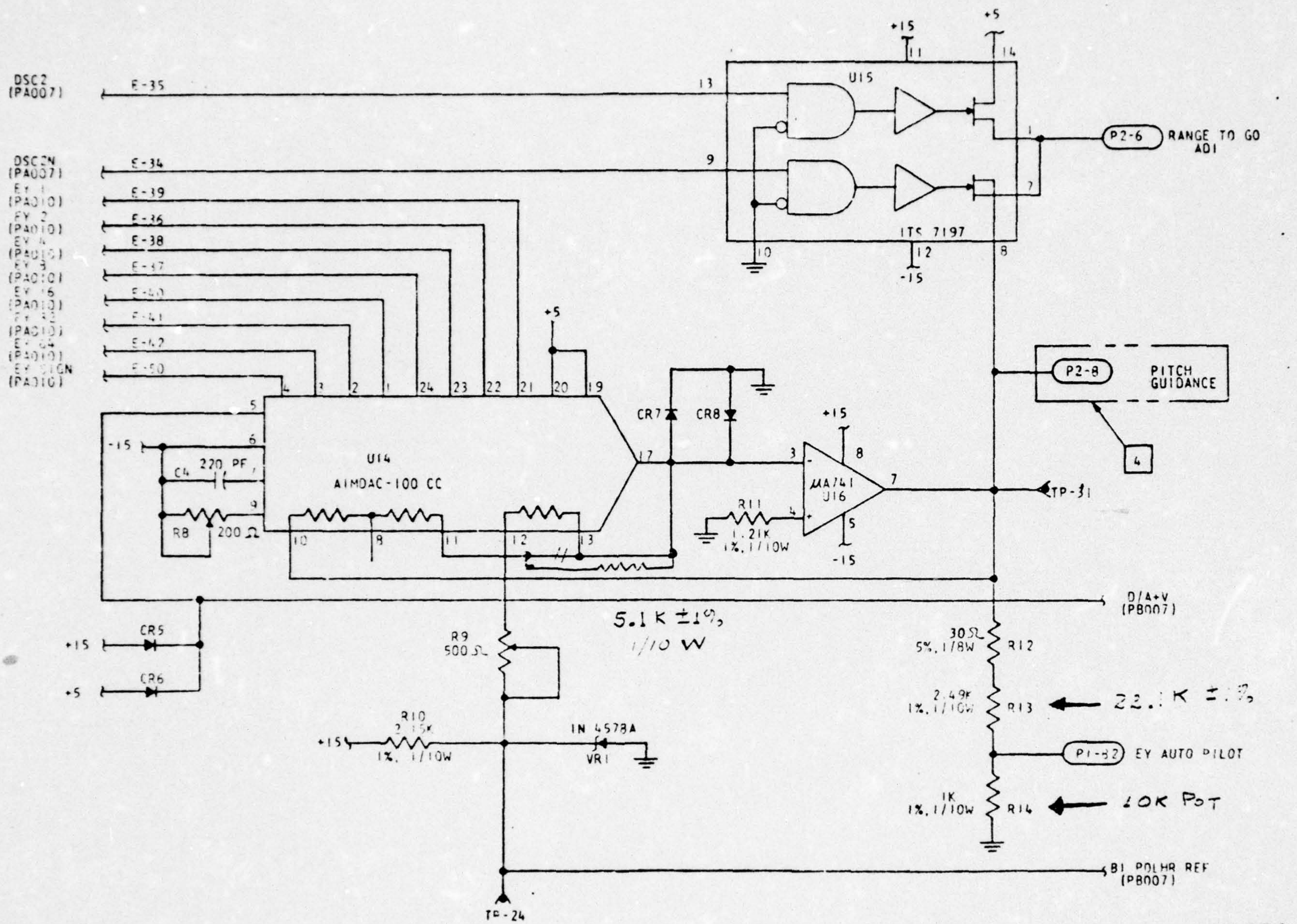


Figure 2-4 YAW CHANNEL

PB007

SIZE	CODE IDENT NO	DWG NO
C	03640	G222839



PB006

SIZE	FSCM NO	DWG NO
C	03640	6222839
SCALE -	REV C	SHEET 5

Figure 2-5 PITCH CHANNEL

2.5.4 Acceptance Testing

All modified hardware shall be tested in accordance with test procedures as defined in Reference 2-2; WGSS/SSM Acceptance Test Procedures, IBM No. 76-A64-004, IBM, Owego, NY, 15 October 1976.

3.0 ANTENNA DESIGN AND TEST STUDY

3.1 INTRODUCTION AND SUMMARY

The objectives of the antenna design and test studies may be summarized as follows:

1. Define a DME data link antenna system, including mounting locations on the HAWK missile, which will assure substantial signal margins when operating with the ALSS DME system for the demonstration flight tests. This includes a primary flight test scenario involving all ground based DME relay stations as depicted in Figure 3-1 and a secondary scenairo, illustrated in Figure 3-2 involving airborne relay stations.
2. Determine a preferred mounting location on the HAWK for a pre-defined telemetry antenna which will assure pattern coverage with gain exceeding -10dbi over 90 percent of the lower hemisphere.
3. Determine preferred mounting locations on the HAWK for two pre-defined elements of a Weapon Command Destruct antenna system which will assure spherical coverage with gain exceeding -10dbi over 90 percent of the pattern.

These objectives were accomplished through a combination of scale model pattern measurements and data link performance analysis. A quarter scale aluminum-model of the HAWK missile, a fiberglass radome and quarter scale antennas were fabricated and used to conduct antenna patterns measurements in the IBM Owego anechoic chamber test facility.

It should be noted that the antenna performance analysis described in in this section involved consideration of Carmen site as one GRBS location. Spray site has subsequently selected as a preferred site but the relatively small change (1nm) is not expected to affect antenna performance.

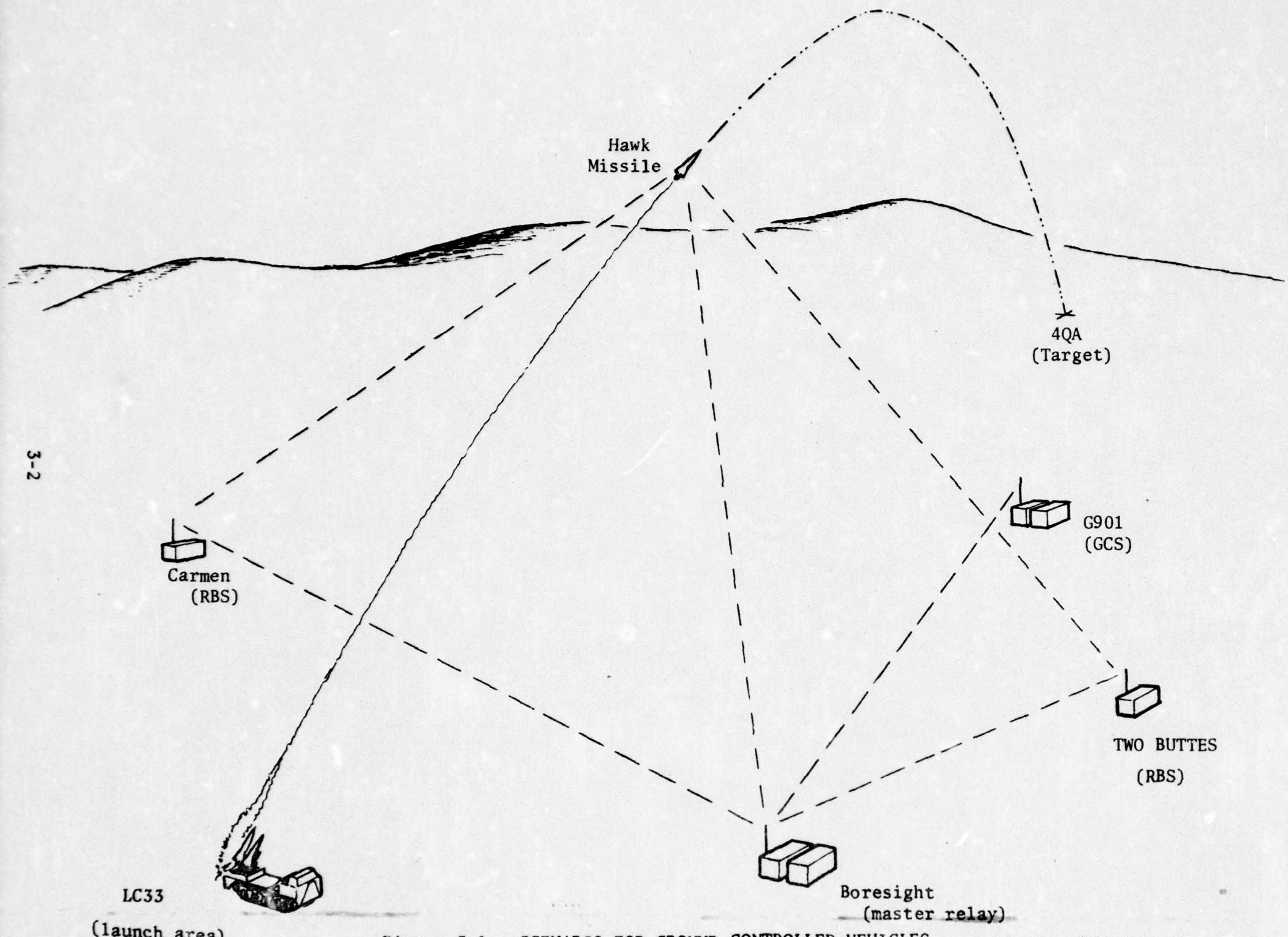


Figure 3-1 - SCENARIO FOR GROUND CONTROLLED VEHICLES

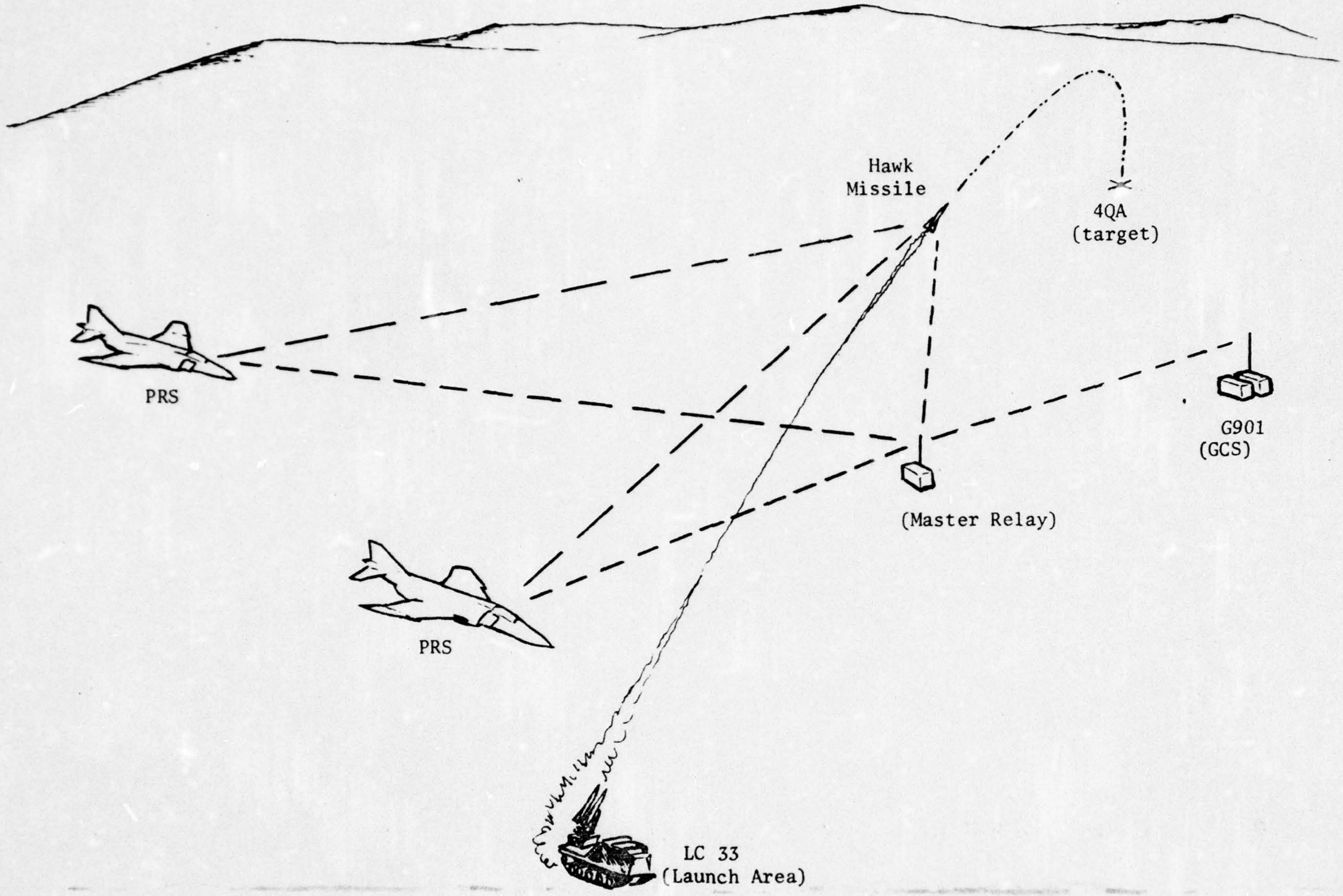


Figure 3-2 - SCENARIO FOR AIRBORNE CONTROLLED VEHICLES

Antenna pattern data taken during the model test program included principal plane (pitch, roll, and yaw) patterns in addition to great circle cuts thru the pitch plane in 15 degree increments. Complete results are included in Appendices A, B, C and D and will be discussed in detail later. Gain measurements were made using a standard gain source as a reference. The standard gain reference level is shown on the pitch plane pattern of each pattern set. This reference level can be used for all additional patterns within the set.

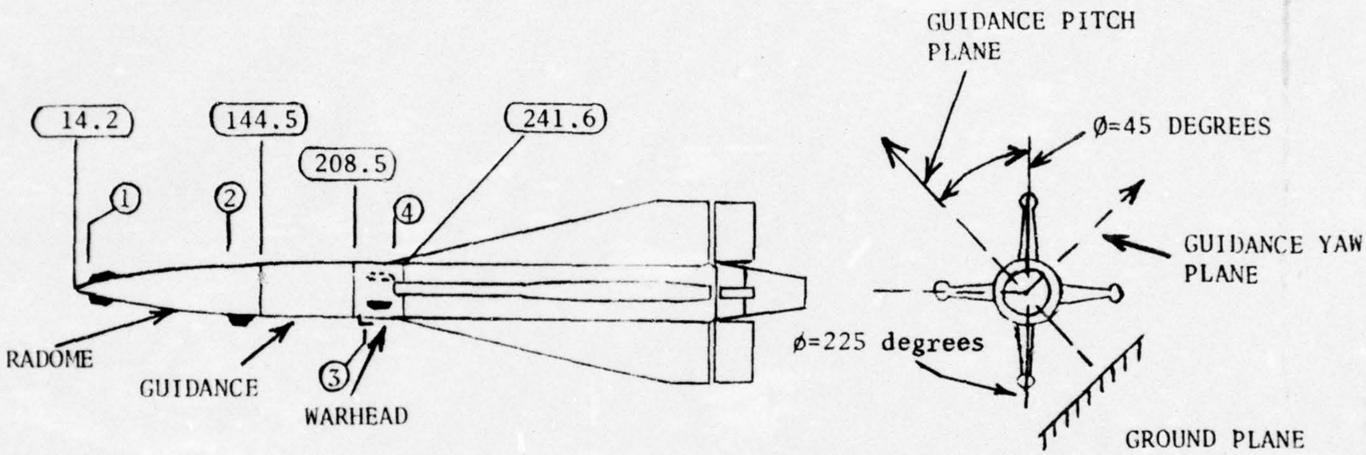
The antenna locations evaluated on the HAWK missile were limited to the radome and warhead sections. The guidance section was not considered because of internal hardware constraints.

During the study, two DME antenna configurations were established for the flight test program. A single slotted blade antenna was developed for ground control ranging and guidance and a two element (slotted blade) antenna arrangement was configured for ranging and guidance with airborne relay stations. Analysis of DME data link performance for these designs and the corresponding flight test scenarios indicates a worst case signal margin of 8-10db for the ground based control case and more than 15db for the airborne relay case.

The optimum antenna locations selected from the scale model data are illustrated in Figure 3-3 and may be summarized as follows:

- o DME Ground Controlled Vehicles - The DME antenna will be located in the aft section of the radome (bottom of missile)
- o DME Airborne Controlled Vehicles - The DME antennas will be located in the forward section of the radome (top and bottom of missile)

HAWK MISSILE



ANTENNA SYSTEM	LOCATION
1 DME (AIRBORNE CONTROLLED VEHICLES)	34.5
2 DME (GROUND CONTROLLED VEHICLES)	129.3
3 TELEMETRY	222.0
4 COMMAND DESTRUCT	232.2

* ALL DIMENSIONS IN CENTIMETERS

Figure 3-3 - HAWK MISSILE COMPOSITE ANTENNA LOCATIONS

- Telemetry antenna will be located in the warhead section (bottom side of missile)
- Command guidance antennas will be located on the warhead section in-line with the wings at 45° and 225° from the guidance pitch plane.

The following subsections describe the individual antenna design, test and analysis results in more detail.

3.2 DME ANTENNA SYSTEM GROUND CONTROLLED VEHICLES

The DME weapon antenna selected for ground controlled vehicles is a slotted blade antenna. This antenna type provides the basic lower hemispherical coverage required for the ground controlled vehicles scenario (Figure 3-1). Electrical pattern measurements were conducted with the antenna mounted in two locations on the weapon, namely, the warhead and radome sections. When the antenna was mounted in the warhead section, a fiberglass radome was used during the measurements. In this case, the warhead section itself provides a sufficient ground plane for the antenna. A metallic nose cone was used in place of the fiberglass radome when the antenna was moved forward and installed in the radome section.

A comparison of both sets of data taken indicated that both locations provided adequate pattern and gain coverage. As a result of the total test program, it was decided that since both the Telemetry and Command Destruct antennas would be best located in warhead section, the DME antenna should be located in the radome section as shown in Figure 3-4. Estimated full scale antenna dimensions are given in Figure 3-5. Final dimensions will be established when a full scale unit is fabricated and tested in the Phase II effort of the SSM Program.

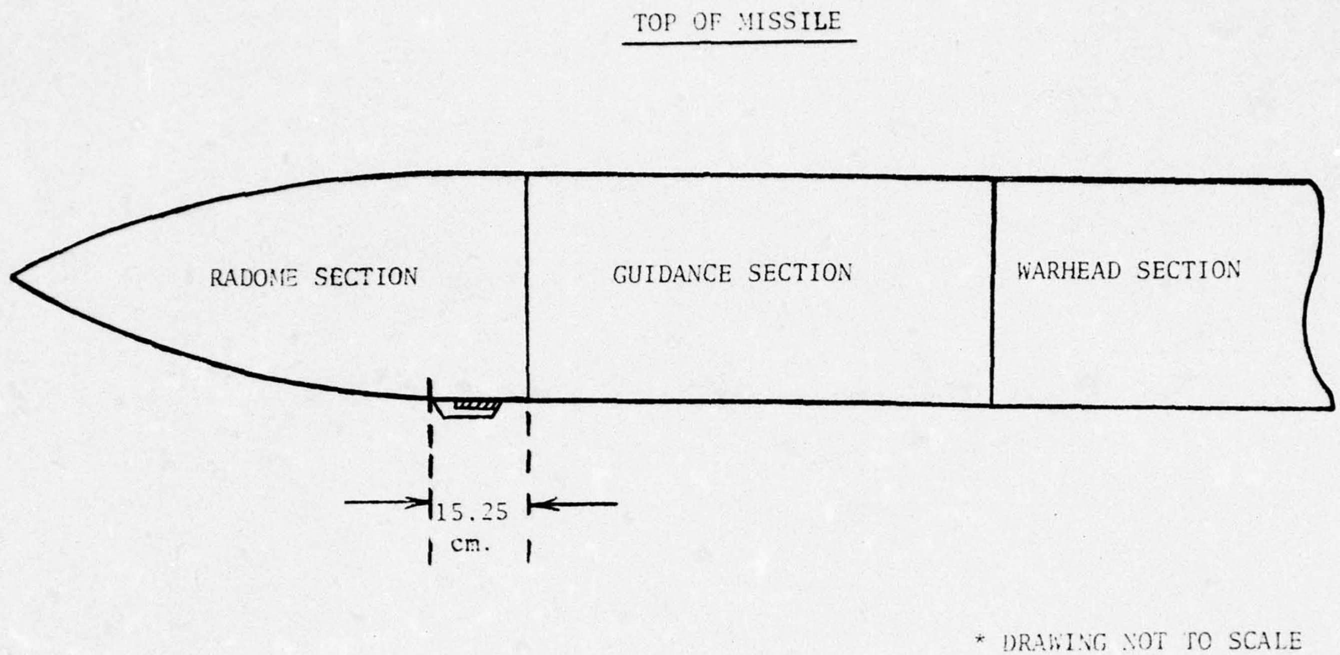


Figure 3-4 - DME ANTENNA LOCATION (GROUND CONTROLLED VEHICLES)

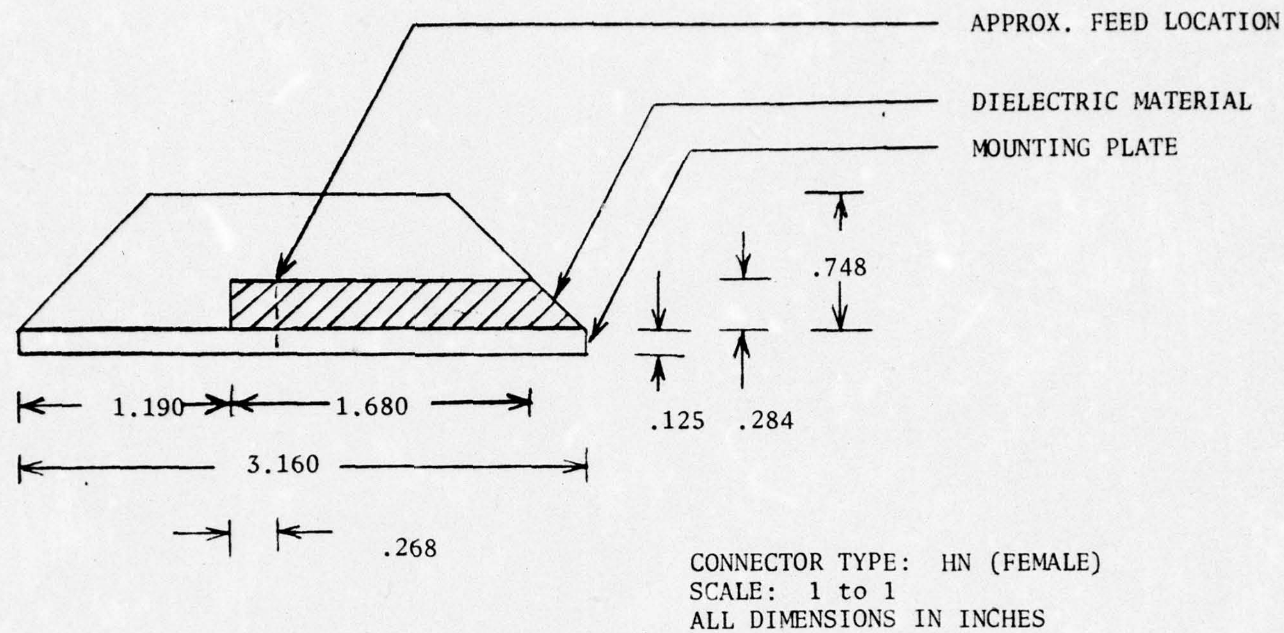


Figure 3-5 - ESTIMATED DME ANTENNA DIMENSIONS

The patterns and gain measurements with the antenna located in the radome section are shown in Appendix A. Analysis of this data shows that the antenna provides sufficient systems coverage (hemispherical) at all required angles with a peak gain of approximately +4dBi. A systems power budget shown in Table 3-1 gives the signal margin at impact for the various ground sites considered. In addition, the DME/HAWK simulation program was modified during the Phase I effort to determine the required weapon antenna gain from launch to impact. Two specific non-nominal trajectory cases were evaluated,

1) Elevation angle ($QE=55.68^{o}$) , 2 degrees above nominal

2) Azimith Angle= -87.49^{o} , 2 degrees to the left of nominal

The transmission path considered for the simulation runs was downlink (weapon to the ground sites). The significant hardware parameters used in this analysis were,

P_T (Transmitted Power) = +66 dbm

KTB_N (Thermal Noise) = -104 dbm (10 MH_Z Bandwidth)

N_F (Noise Figure) = 12 db

L (Losses) = 7 db

Ground Station Antenna Pattern (See Figure 3-6)

(S/No) (Signal to Noise Ratio) = 13 db

Figures 3-7 thru 3-9 show the required vs actual (worse case) DME antenna gains for cases 1 and 2 for Carmen, Boresight and Two Buttes respectively. The minimum signal strength margin seen in this comparison is not due to a lack of coverage on the weapon antenna but is a result of a -22 db null region in the ALSS ground station antenna which occurs at approximately 30^{o} above the horizon (refer to Figure 3-6). An investigation of a number of ALSS antennas over the full frequency range shows that this null is inherent in the antenna design, remains at approximately 30^{o} and is within the same gain level ($\pm$ 2 db). The overall worse case signal margin, as shown in Figures 3-7 thru 3-9 is approximately 8 - 10 db. With all parameters

TABLE 3-1 POWER BUDGET FOR GROUND & AIRBORNE CONTROLLED VEHICLES

	TRANSMIT				PATH LOSS		RECEIVER POWER				RECEIVER E/NO						MARGIN
							SIGNAL		NOISE								
LINK	P_a dBm	L_t dB	P_t dBm	G_t dBi	R n Mi	L_p dB	G_r dBi	P_r dBm	N_f dB	N_o dBm	P_r/N_o dB	T dB	E/N_{ob} dB	Loss dB	E/N_{oa} dB	E/N_{or} dB	M dB
G901 to 2 Buttes	70	4	66	8	8.4	-118	8	-36	12	-162	126	-65	61	4	57	13	44
2 Buttes to Boresight	70	4	66	8	20.6	-126	8	-44	12	-162	118	-65	53	4	49	13	46
2 Buttes to Carmen	70	4	66	8	26	-128	8	-46	12	-162	116	-65	51	4	47	13	34
G901 to Boresight	70	4	66	8	24	-127	8	-45	12	-162	117	-65	52	4	48	13	35
Boresight to 4QA	70	4	66	8	29.5	-129	0	-55	9	-165	110	-65	45	3	42	13	29
4QA to Boresight	66	3	63	0	29.5	-129	8	-58	12	-162	104	-65	39	4	35	13	22
Carmen to 4QA	70	4	66	8	24	-127	0	-53	9	-165	112	-65	47	3	44	13	31
4QA to Carmen	66	3	63	0	24	-127	8	-56	12	-162	106	-65	41	4	37	13	24
2 Buttes to 4QA	70	4	66	8	20	-126	0	-52	9	-165	113	-65	48	3	45	13	32
4QA to 2 Buttes	66	3	63	0	20	-126	8	-55	12	-162	107	-65	42	4	38	13	25
PRS to 4QA	70	2	68	2.9	57.5	135	-4	-68.1	9	165	96.9	-65	31.9	3	28.9	13	15.9
PRS to LC33	70	2	68	2.9	24.7	127	-6	62.1	9	165	102.9	-65	37.9	3	34.9	13	21.9
4QA to PRS	66	3	63	-4	57.5	135	2.9	73.1	7.5	166.5	93.4	-65	28.4	2	26.4	13	13.4
LC33 to PRS	66	3	63	-6	24.7	127	2.9	67.1	7.5	166.5	99.4	-65	34.4	2	32.4	13	19.4

TABLE 3-1

(continued)

Definition of Terms in Power Budget:

P_a = Transmitter output power

L_t = Transmit system losses

P_t = Transmitter power at antenna

G_t = Transmitter antenna gain

R = Range

L_p = Path loss

G_r = Receiver antenna gain

P_r = Power received

N_f = Noise figure

No = KTB_n = Thermal noise = 174 dBm (Noise/H_z)

T = Time bandwidth product

E/NO = Signal to noise ratio

M = Signal margin above required receiver signal to noise ratio

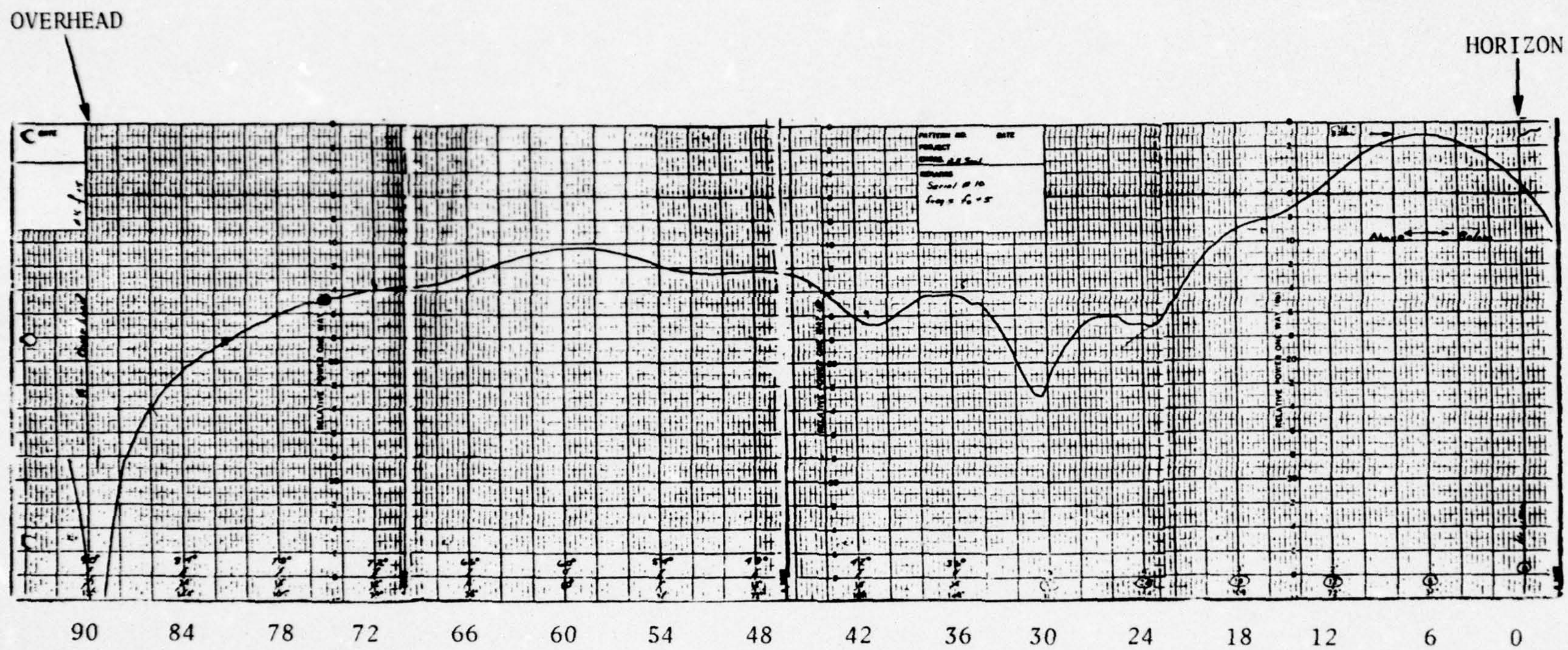


Figure 3-6 - ALSS GROUND STATION ANTENNA PATTERN

NO. 340R-10 DIETZGEN GRAPH PAPER
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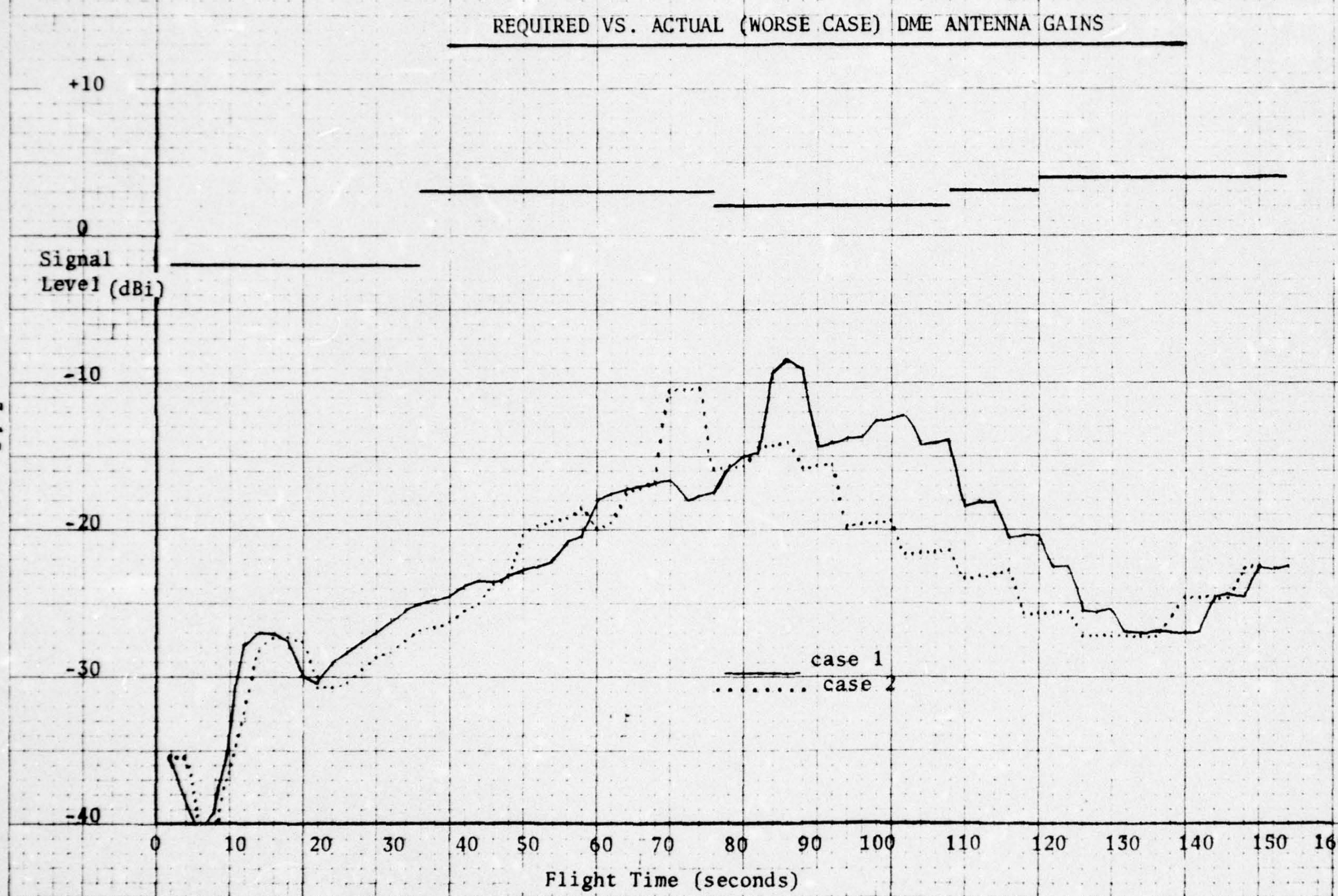


Figure 3-7 - CARMEN

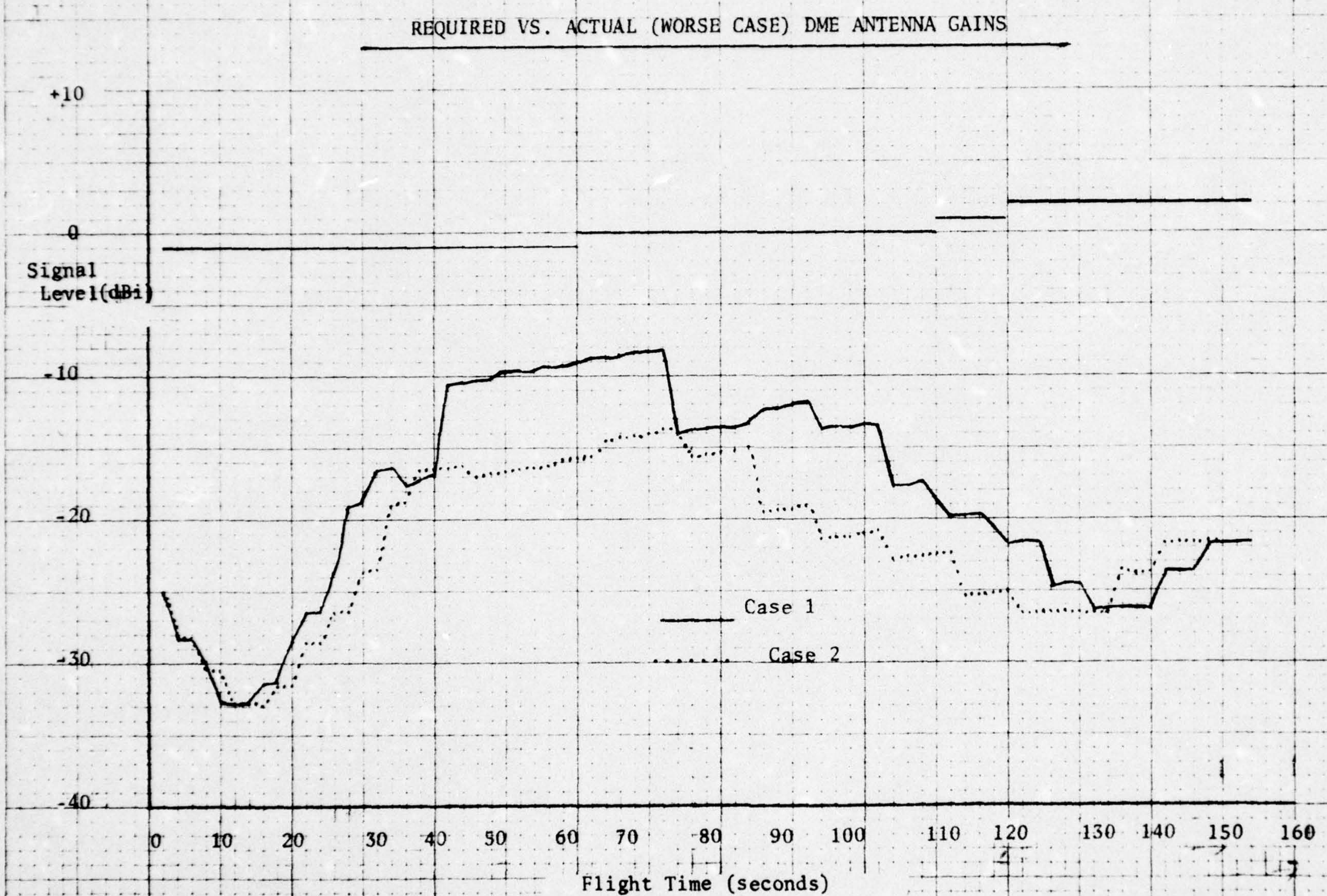


Figure 3-8 - BORESIGHT

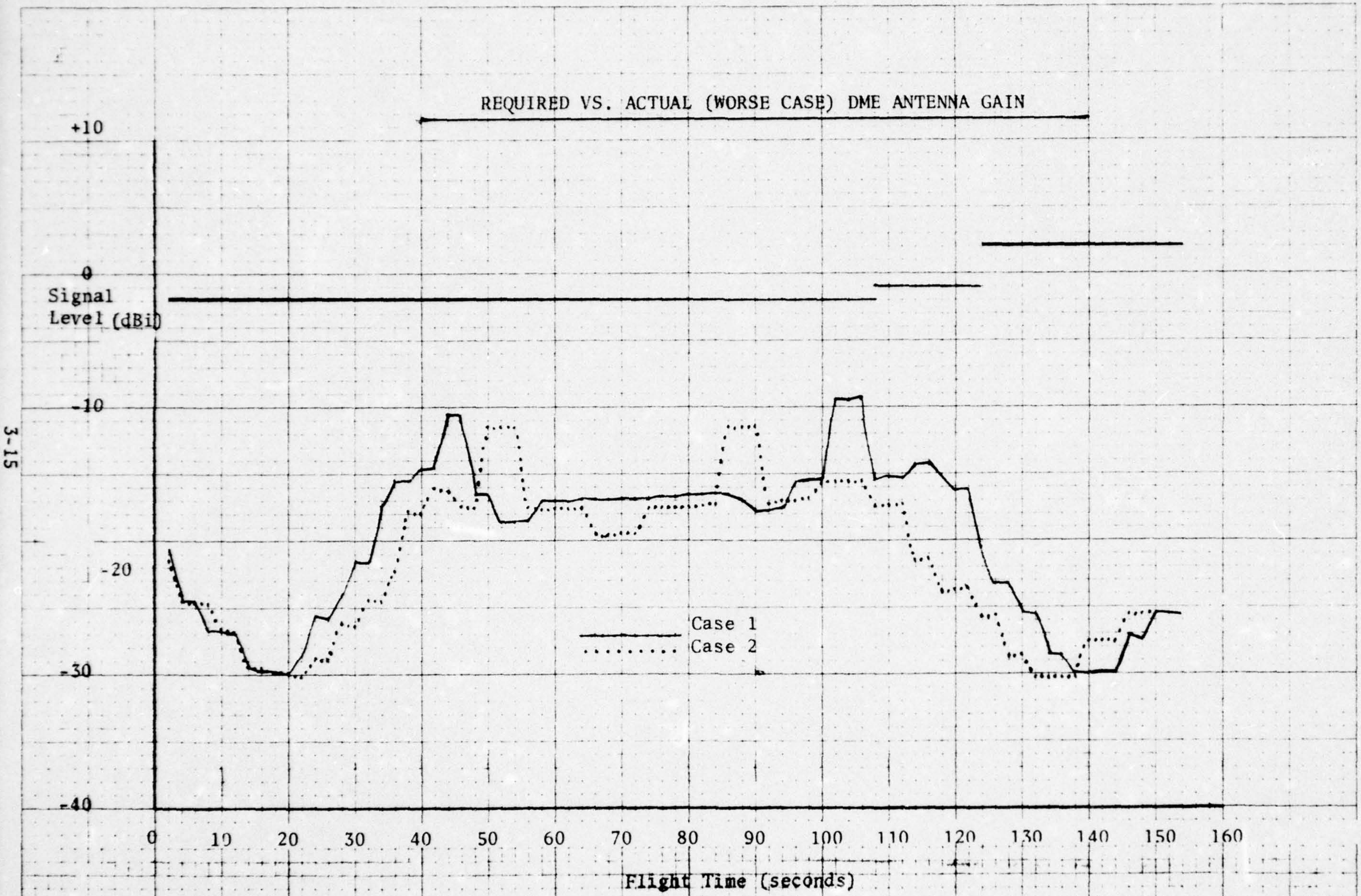


Figure 3-9 - TWO BUTTES

considered, however, the signal margin is sufficient for continuous data link communications.

Since the selected DME antenna installation will be on the dielectric radome, it will be necessary to apply a good conductive paint (e.g. Eccoshield ES) to the radome outer surface prior to mounting the antenna. This treatment is required to assure pattern and gain repeatability from the quarter scale model to the full scale weapon.

3.3 DME ANTENNA SYSTEM AIRBORNE CONTROLLED VEHICLES

Optimum data link coverage for the airborne PRS Guided Hawk flights, requires a two antenna system providing spherical coverage. The antenna system includes a pair of slotted blade antennas whose RF is summed in a low loss combining network. The antennas are located in the guidance pitch plane and oriented as shown in Figure 3-10. The antenna patterns for this configuration are shown in Appendix B. The combined antenna patterns show an average pattern gain reduction at most angles of approximately 4-6db below a single antenna element but the overall angular coverage of the two antenna system far exceeds a one antenna system for aircraft weapon guidance. Preliminary data was first taken with the combined antenna system in the same physical position as the single DME antenna system. The antenna separation (approximately 1λ) at this location resulted in unacceptable pattern deterioration (multi-lobing) which would have possibly contributed to data link dropouts during system tests. To eliminate this problem, the antennas were moved as far forward as possible on the radome while still maintaining clearance for the antenna connectors/cabling. The antenna separation at the selected location is approximately $.5\lambda$.

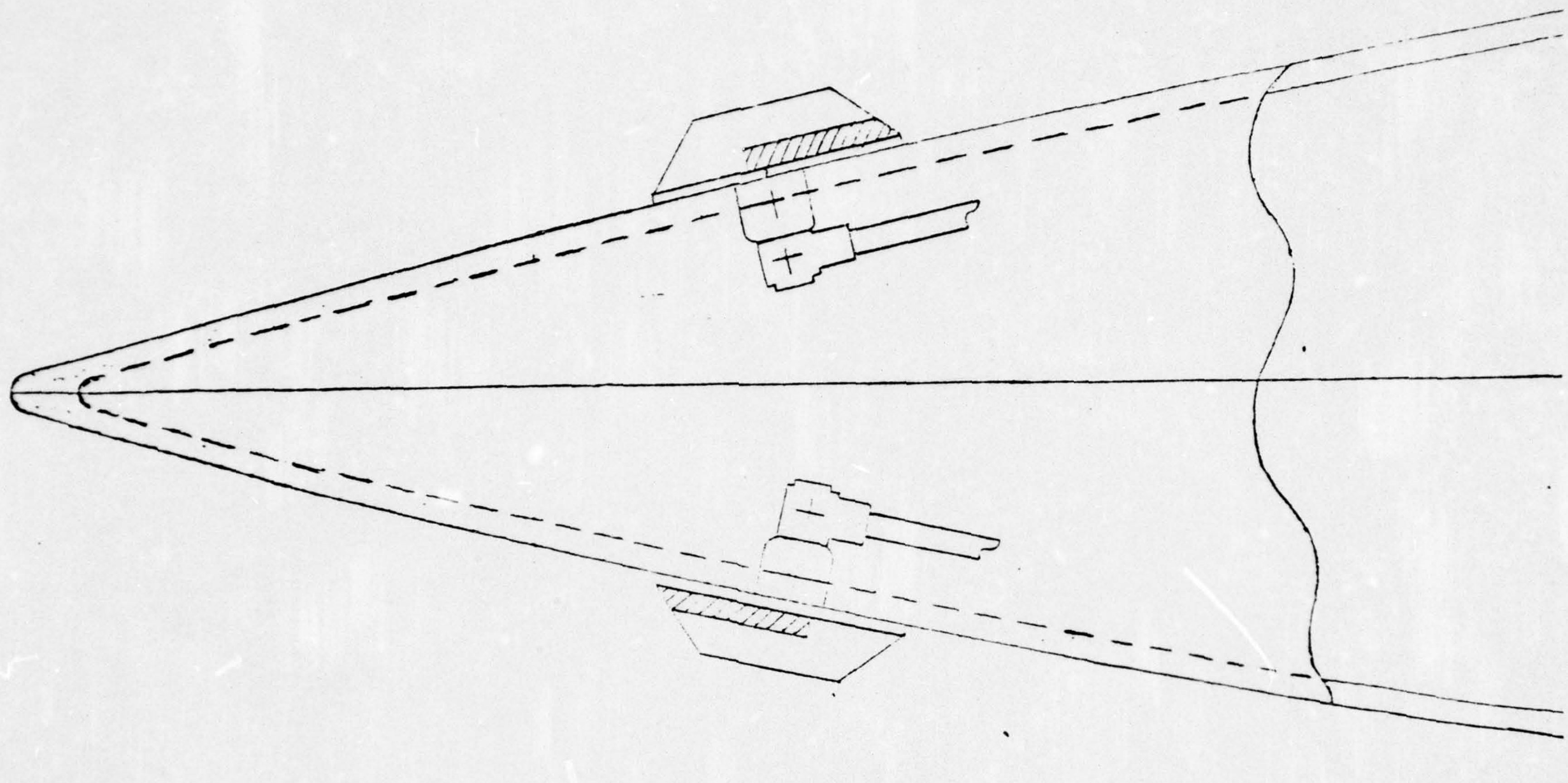


Figure 3-10 DME ANTENNA CONFIGURATION
PRS GUIDANCE

In a representative airborne relay station flight test scenario the PRS aircraft will fly at an altitude of 40,000 feet and a range of 25 nautical miles behind the launcher as shown in Figure 3-11. The power budget and resulting signal margin for this condition is listed in Table 3-1 as 13 db or greater.

The data link performance for other PRS flight profiles can be evaluated by using the PRS pod antenna patterns (Figures 3-12 and 3-13) and the ALSS ground antenna patterns (Figures 3-6) to establish an acceptable signal margin for the flight test.

3.4 TELEMETRY ANTENNA LOCATION TESTS

The Hawk missile will contain a telemetry system to privide performance evaluation and fault isolation during flight test. Maintaining a continuous telemetry link through all phases of flight necessitates hemispherical antenna coverage. The full scale telemetry antenna is manufactured by TECOM Industries, Inc., is a vertically polarized blade antenna and operates in the 2.2 - 2.3 GH_z frequency range.

Quarter scale pattern data was taken with a simulated blade antenna on the underside of the HAWK missile warhead section, just forward of the wings.

Antenna pattern data was taken using a circularly polarized transmitting source. Data measured include the principal plane pitch, roll and yaw patterns in addition to cuts thru the pitch plane at 15 degree increments and are shown in Appendix C.

The antenna peak gain is approximately +3 dBi and provides hemispherical coverage on the underside of the weapon. Analysis of all data measured indicates an overall hemispherical pattern gain figure of greater than - 10 dBi over at least 95% of the pattern angles measured and is well within the 90% coverage requirement needed for optimum systems operation.

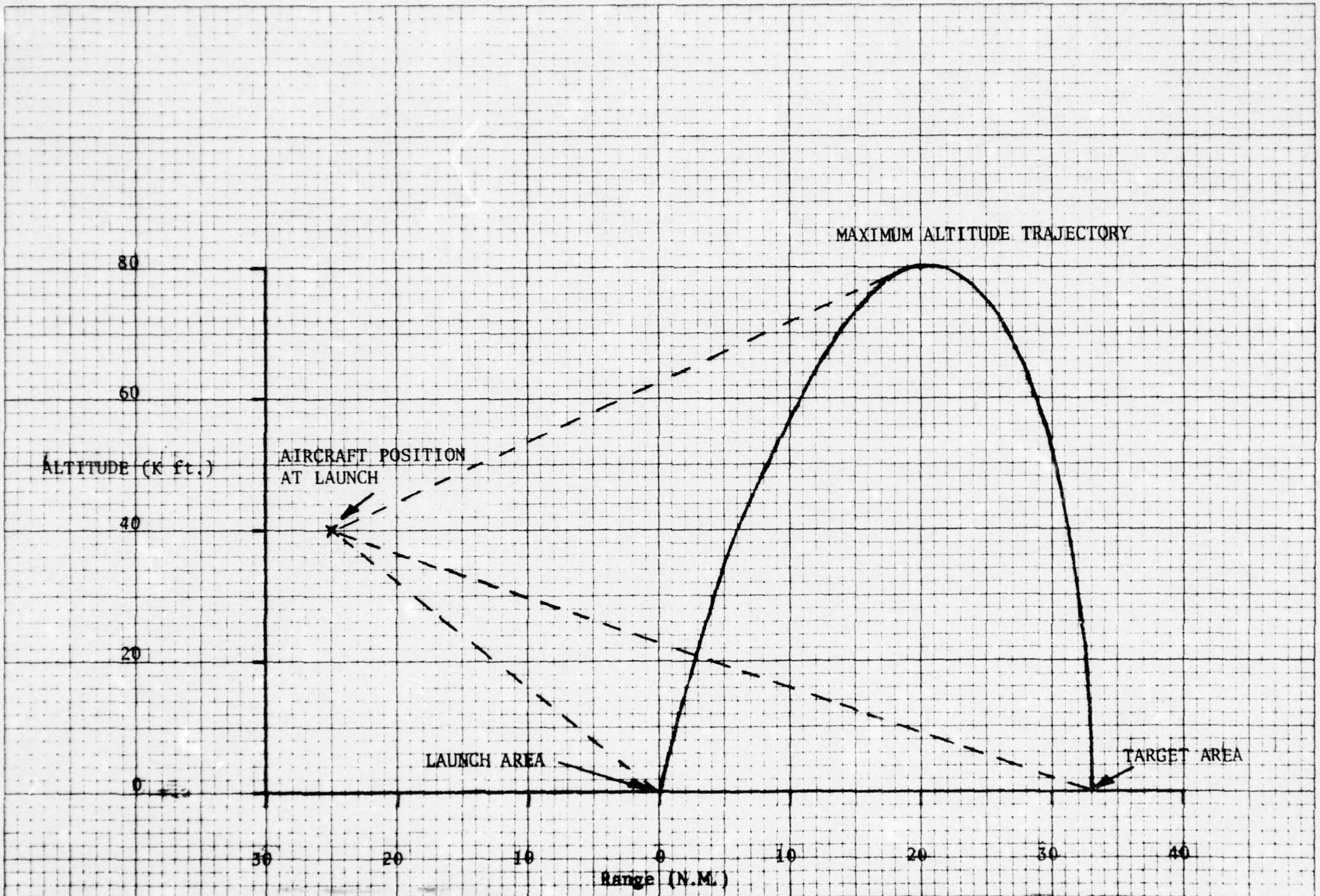


Figure 3-11 - PROPOSED AIRBORNE FLIGHT INITIAL CONDITIONS

COVERAGE WITH PRS AT INBOARD WING STATION, WITH WING TANKS

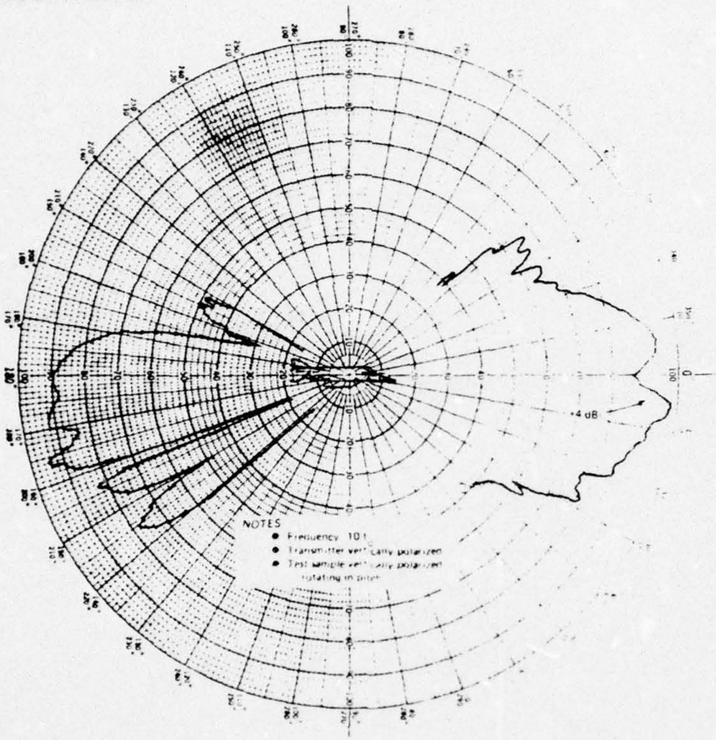


Figure 3-12 - TYPICAL PRS POD ANTENNA ELEVATION PATTERN

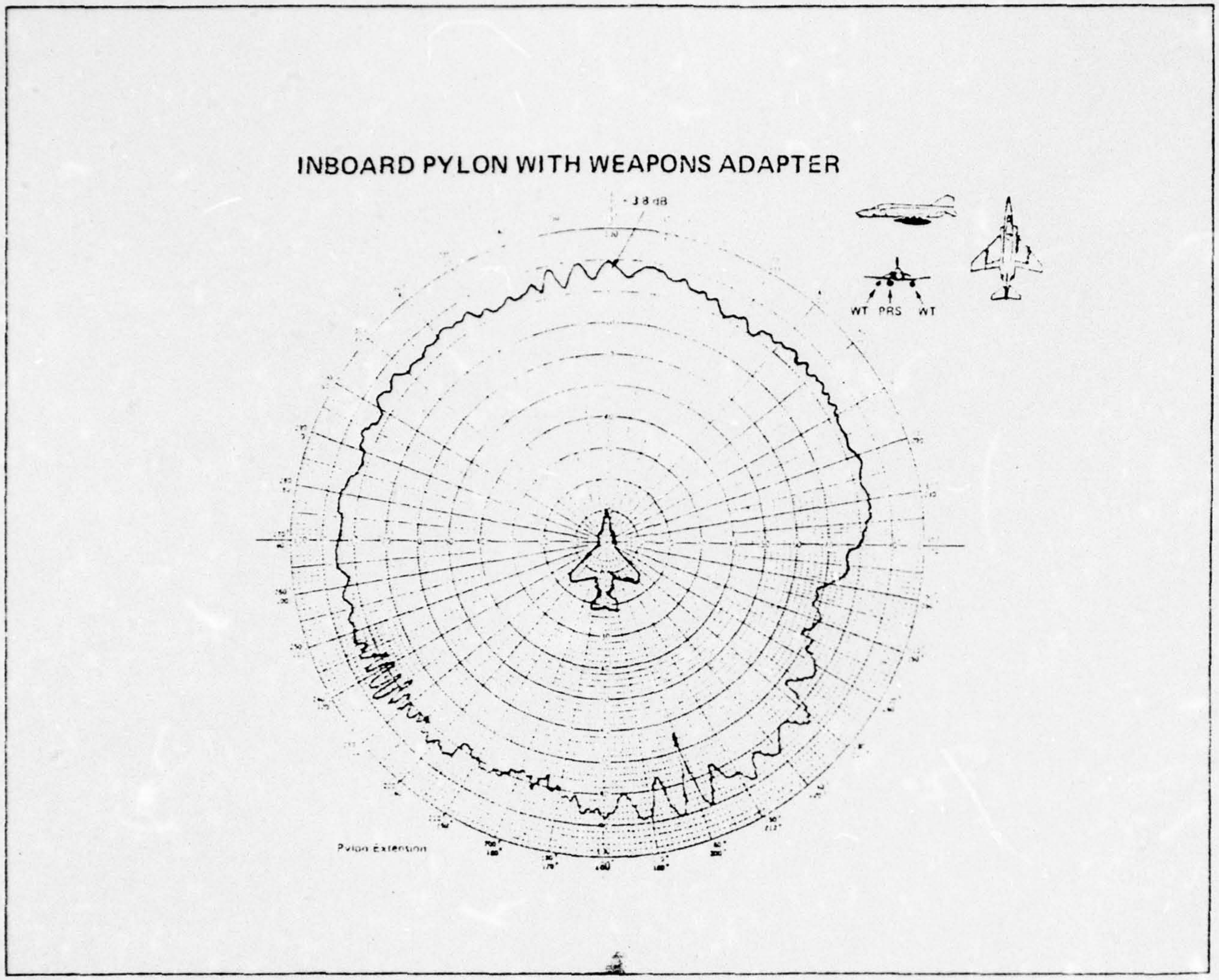


Figure 3-13 - TYPICAL PRS POD ANTENNA AZIMUTH PATTERN

A detailed installation drawing of the recommended telemetry antenna location on the missile is shown in Figure 3-14.

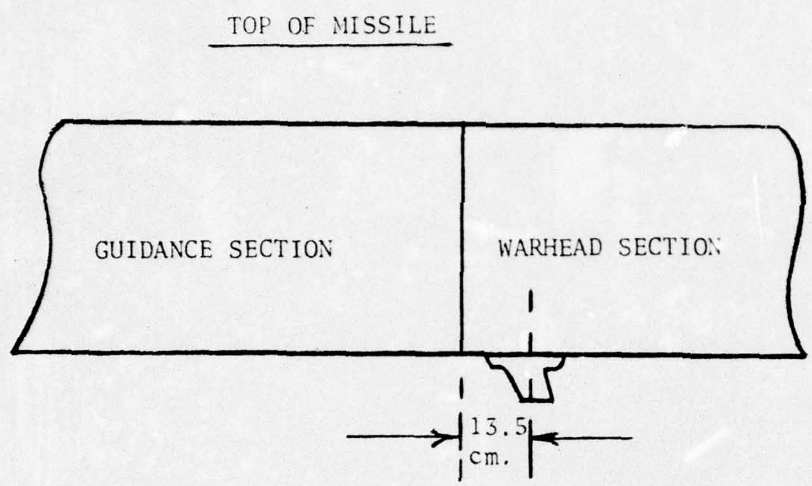
3.5 COMMAND DESTRUCT ANTENNA LOCATION TESTS

The Weapon Command Destruct system requires spherical antenna coverage to assure destruct capability for all weapon orientations. To meet this requirement a pair of antennas is needed. The antenna assembly consists of two vertically polarized slotted blades fed 180^{o} out of phase and summed in a coaxial "T". The full scale antenna system operates at 409 MH_z.

The antennas were mounted in the warhead section and oriented in-line with the weapon wings at angles of $\emptyset = 45$ degrees and $\emptyset = 225$ degrees as referenced to the guidance roll plane as shown in Figure 3-3. Principal plane patterns were measured on the model in addition to 15 degree cuts thru the pitch plane which are shown in Appendix D. The patterns were measured using a circularly polarized transmitting source. The two antenna combination provides sperical pattern coverage and has a peak gain of approximately 6-7 dBi.

The overall pattern gain for this configuration exceeds 90% coverage at the -10 dBi signal level for the pattern angles measured.

A detailed drawing of the recommended installation is shown in Figure 3-15.



* DRAWING NOT TO SCALE

Figure 3-14 - TELEMETRY ANTENNA LOCATION

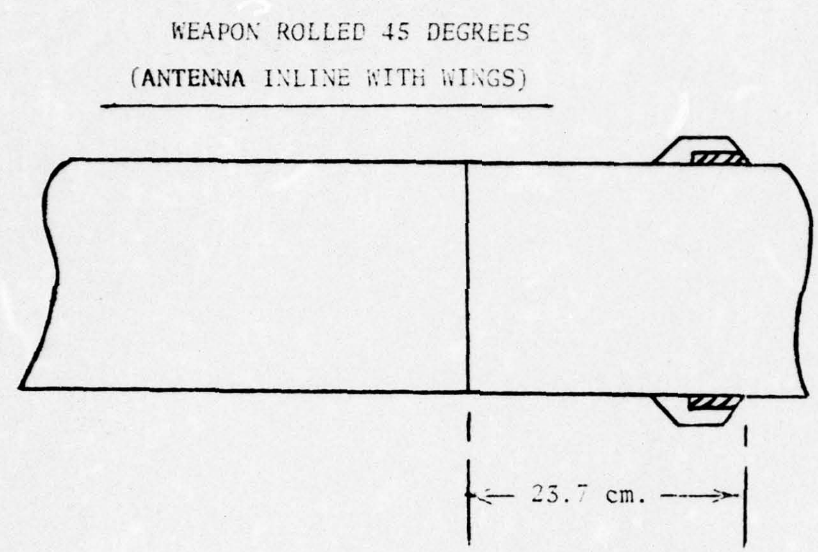


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Figure 3-15 - COMMAND DESTRUCT ANTENNA LOCATION

4.0 DEMONSTRATION FLIGHT TEST GEOMETRY DEFINITION

Figure 4-1 illustrates the system deployment geometry which has been established for the DME/Hawk demonstration flight tests. Table 4-1 lists the location of pertinent ground sites in ALSS coordinates. This list includes some sites (Carmen, 4Q, Army II) which were considered in preliminary analysis but which are not included in the current configuration shown on Figure 4-1.

4.1 WEAPON TRAJECTORY DEFINITION

All weapon trajectories will be the same; from Launch Complex 33 to the target area designated as 4QA. It may be noted in Table 4-1 that this target location is designated with tolerances of ±1nm, indicating that the general target area has been selected, but a final definition of the specific target point has not been made. Selection of this trajectory is based on the following general considerations:

1. Launch Complex 33 has superior missile launch test instrumentation facilities.

2. The 4QA target area corresponds to the desired weapon range of approximately 50KM.

3. The 4QA target area is consistent with range safety guidelines.

4. The 4QA target area has provisions for Photo-Theodolite coverage desired for the terminal flight phase.

5. The 4QA target area is preferred over an alternate candidate in the 4Q area because it has less potential for DME data link disruption due to terrain masking by the hills on the west side of the range.

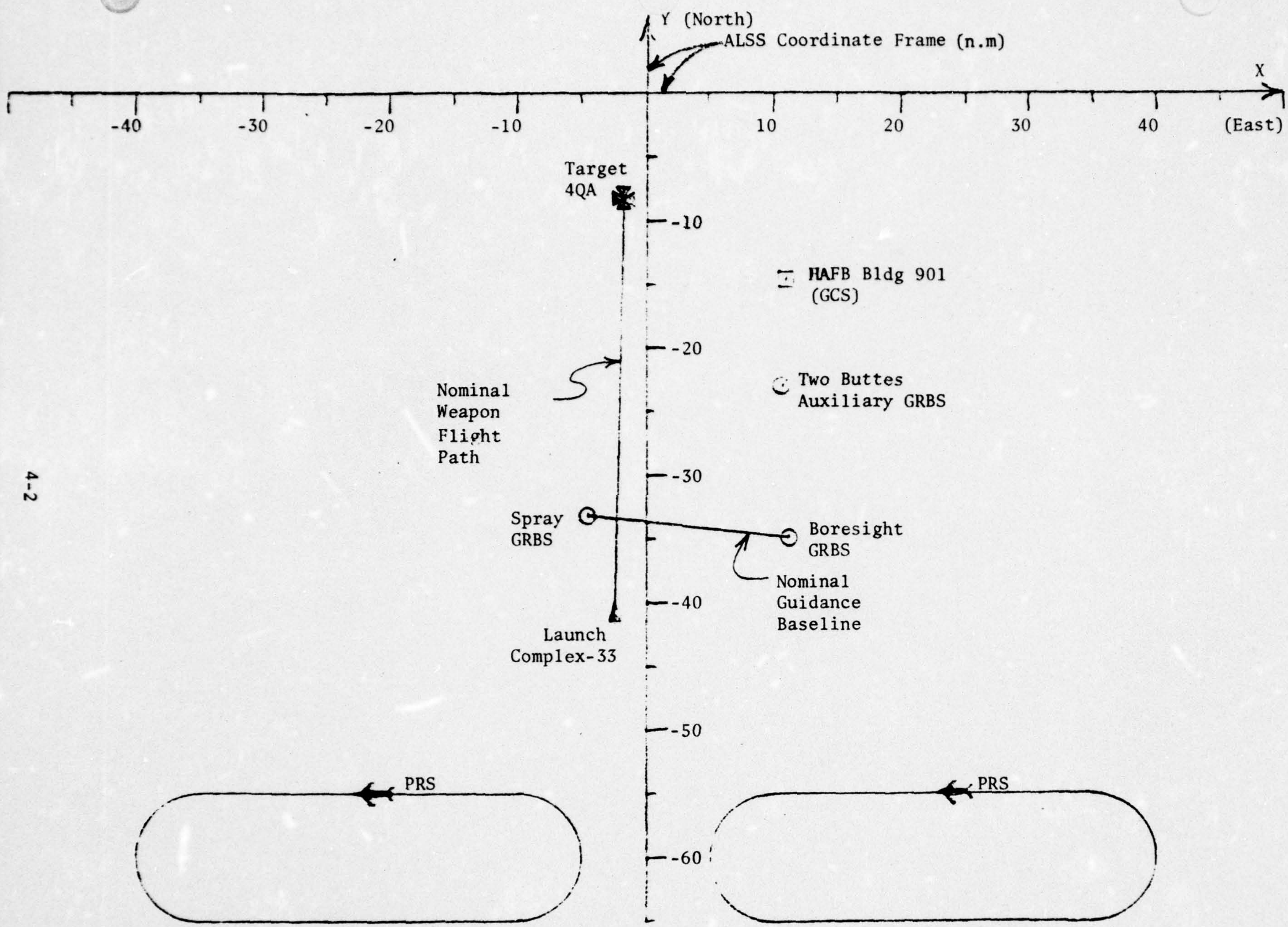

Figure 4-1 DME/SSM DEMONSTRATION FLIGHT TEST GEOMETRY

TABLE 4-1

SITE LOCATIONS CONSIDERED FOR DME/SSM DEMONSTRATION FLIGHT TESTS

SITE	LOCATION IN ALSS COORDINATES (nm)		
	X (EAST)	Y (NORTH)	Z (VERTICAL)
Launch Complex 33	- 2.2908	-40.8220	0.4116
HAFB Bldg 901 (GCS)	10.8021	-14.4193	0.6315
Bore Sight Tower	11.0375	-34.9982	0.5924
Spray Site	- 4.7821	-33.5767	0.5075
Two Buttes	10.4567	-22.7503	0.6938
Target 4QA	- 2.0±1.0	- 8.0±1.0	0.6200
Target 4Q	- 5.8820	-10.9267	0.6197
Carman	- 5.0704	-35.0803	0.4883
Army II	-5.4085	-28.6358	0.6031

4.2 ALSS SITE SELECTION FOR GROUND BASED WEAPON GUIDANCE

The ALSS ground station configuration to be used for those flights controlled entirely by ground stations is as follows:

Building 901-HAFB .... Ground Control Station (GCS)
Boresight Tower .... Master Ground Relay Beacon Station (GRBS)
Spray Site .... Slave 1 GRBS
Two Buttes Site .... Slave 2 (Auxiliary) GRBS

Bore Site and Spray are designated as the DME guidance baseline and thus will be the only stations from which the DME range measurements used in weapon guidance will be made. Range measurements from the auxiliary GRBS at Two Buttes will be used only in the three-range navigation solution which will provide an independent three-dimensional track of weapon location for use by range safety personnel and for use in post flight analysis.

A primary consideration in this site selection were the results of preliminary field tests at WSMR by ASD-Det 1 personnel of data link line-of-sight communication capabilities for a number of candidate site locations. These tests were performed because the ALSS is designed for operational employment with at least one airborne DME relay station and consequently, will provide the DME functions necessary for the DME/Hawk demonstration flight test, with no airborne elements other than the weapon, only if the ground station sites are selected to allow one or more of the following modes of operation:

1. <u>GCS Master</u>

   Line of sight communication is possible between the GCS and two GRBSs used as the guidance baseline.

2. <u>Baseline Station Master Relay</u>

   Line of sight communication is possible between the GCS and one guidance baseline GRBS which has line of site to the other baseline GRBS.

3. Auxiliary Station Master Relay

Line of sight communication is possible between the GCS and an auxiliary master relay station which has line-of-sight to the two guidance baseline GRBSs.

In addition to the above requirements it is necessary that at least one station, preferably the master, have line of sight to the target area. This is necessary to allow a functional simulation of the blind guidance processing which would be used in an operational system. In this concept, blind guidance would be demonstrated by inhibiting the DME ranging function after the weapon descends below a selected altitude to simulate loss of line-of-sight. The GCS computer will simulate the command extrapolation calculations, which would be performed by an onboard processor in an operational system, and the resulting commands will continue to be sent to the vehicle all the way to impact. If line-of-sight from the master to the weapon is really lost prior to impact the WGSS will hold the last received commands. Consequently, a less meaningful evaluation of blind guidance performance would be obtained.

A less critical but highly desirable capability is that line-of-sight be provided from both guidance baseline stations to the target area down to several hundred feet above the target. This would allow at least the first weapon flight to be controlled all the way to impact to verify basic guidance system operation prior to initiation, on subsequent flights, of the simulated blind guidance tests.

A requirement also exists for line-of-sight between either the GCS or the master relay station and the launch site. This capability is needed to facilitate the preflight weapon tests. With this capability, weapon commands would be communicated from the GCS to the weapon prior to launch to provide final validation of the interface between the WGSS and the weapon flight control system electronics. If line-of-sight is also provided from the two guidance baseline ground stations to the launcher, the preflight tests may also include a test of DME station and weapon biases. This capability is highly desirable for flight test since it would provide an indication of the contribution of DME bias errors to weapon guidance performance and hence, impact accuracy.

The above requirements for data link line-of-sight to obtain various flight test objectives must be traded off against potentially conflicting objectives of performing the flight test with a system configuration approximating as close as possible that which would be expected in an operational DME/SSM deployment scenario. The selected geometry, shown in Figure 4-1, approximates some operational deployment conditions in that the launcher is near the guidance baseline (Boresight and Spray GBRSs) and the trajectory is roughly perpendicular to the baseline.

The preliminary line-of-sight tests at WSMR have indicated some potential data link limitations for this site selection. Lack of line-of-sight from the GCS to the launcher will preclude the GCS master mode of operation and necessitate use of a master relay. Also, since the master relay mode does not facilitate direct range measurements from the GCS to the weapon, an auxiliary slave station must be used to obtain the third range necessary for the secondary three dimensional navigation solution. Boresight has excellent line-of-sight to the GCS and thus can serve as master. Spray cannot be used as a master because the line-of-sight tests revealed that terrain features near this site cause ground clutter returns which interfere with the message relay function.

Two Buttes appears to be a good candidate for the auxiliary station, and could also serve as a master station. Preliminary navigation accuracy analysis, reported in Reference 4-1, indicate a slight accuracy advantage for the selected choice of using Boresite as master.

The preliminary line-of-sight tests also have confirmed the availability of line-of-sight from Boresite, Spray and Two Buttes to the launcher to support preflight tests. These results also assure the potential for initializing the three station navigation solution by locating the weapon on the launcher, prior to weapon launch.

Reference 4-1 "Preliminary DME Navigation Accuracy Analysis for DME/SSM Demonstration Flight Tests," IBM CD-3-76-0183, IBM, Owego, New York. October 1976 (Secret)

4.3 SYSTEM GEOMETRY FOR AIRBORNE RELAY STATION OPERATION

Figure 4-1 previously depicted a preliminary representative geometry for the orbits of two Pod Relay Subsystem (PRS) aircraft operating as airborne relay stations for weapon guidance of the Hawk SSM. The orbits are placed in the positions indicated to provide a baseline behind the launcher and roughly perpendicular to the missile flight path.

The PRS aircraft are assumed to be F-4s flying at 400 Kts TAS at an altitude of 30000 feet. The duration of a Hawk flight is 140 to 150 seconds, therefore, the length of the orbit straight legs must be a minimum of 17 nm in order to assure straight and level flight of the PRS throughout the weapon flight. A value of 25 nm is used to assure some margin for synchronizing the orbits and navigation filter stabilization prior to launch.

The above geometry has been defined as a preliminary baseline to serve as a basis for initial flight test planning. Potential problem areas which must be investigated to confirm or change this selection include the following:

1. Coordination with appropriate WSMR, Air Force, and civilian agencies cognizant with air traffic control in the test area regarding the airspace clearances necessary to fly the aircraft in these orbits which are not contained within WSMR boundaries.

2. Verification of data link line-of-sight from orbit extremes to the target area and DME ground stations.

3. Selection of ground sites for placement of DME Remote Beacon Stations (RBSs) in locations under or near the PRS orbits to enchance PRS navigation accuracy.

The investigation of these airborne mission planning considerations will be accomplished as part of the follow-on Phase II Program. This effort will also include DME navigation error analysis and use of the 6-DOF Hawk simulation Program to investigate overall system performance and accuracy tradeoffs associated with the above airborne delivery geometry, or alternate geometric configurations as appropriate.

5.0 DME/SSM DEMONSTRATION SOFTWARE REQUIREMENT

5.1 INTRODUCTION

One task specified in the DME/SSM Phase I Statement of Work is to monitor the DME/Hawk guidance system design and simulation activity to identify preliminary requirements for the demonstration flight test software. References 5-1 and 5-2 present a detailed description of the ALSS-Weapons Integration Program (ALSS/WI) software, upon which the flight test software will be based. This report reviews the basic ALSS/WI software structure and identifies the specific areas where new or modified software routines must be developed.

Figure 5-1 shows the functional relationships of data processing, control, display and data link elements within the ALSS ground control station (GCS). The SSM software will reside primarily in the navigation computer located within the GCS. The location computer will provide its normal interface between the navigation computer and the DME data link, and also will be used to display weapon flight data for a range safety officer, as discussed subsequently in Section 5.6.

Development of software for the SSM demonstration will rely very heavily on the existing ALSS/Weapon Integration (ALSS/WI) software. The navigation computer software is defined by 10 major functions:

1. Control Panel and CRT Display
2. Executive Control
3. Data Link
4. Navigation Start-up
5. ARS Navigation
6. Weapon Navigation and Guidance
7. Recorders
8. Library
9. Built-in-Simulation
10. Test

References: 5-1 "Final Report for Weapon Integration Program - Vo. III - Software Functional Description," IBM Report No. 76-M55-004, IBM, Owego, NY, 2 April 1976

5-2 "Weapon Integration Program Software Contract End Item Detailed Technical Description (Part II) Operational Program," IBM Spec. No. 6007882, IBM, Owego, NY, 31 January 1976

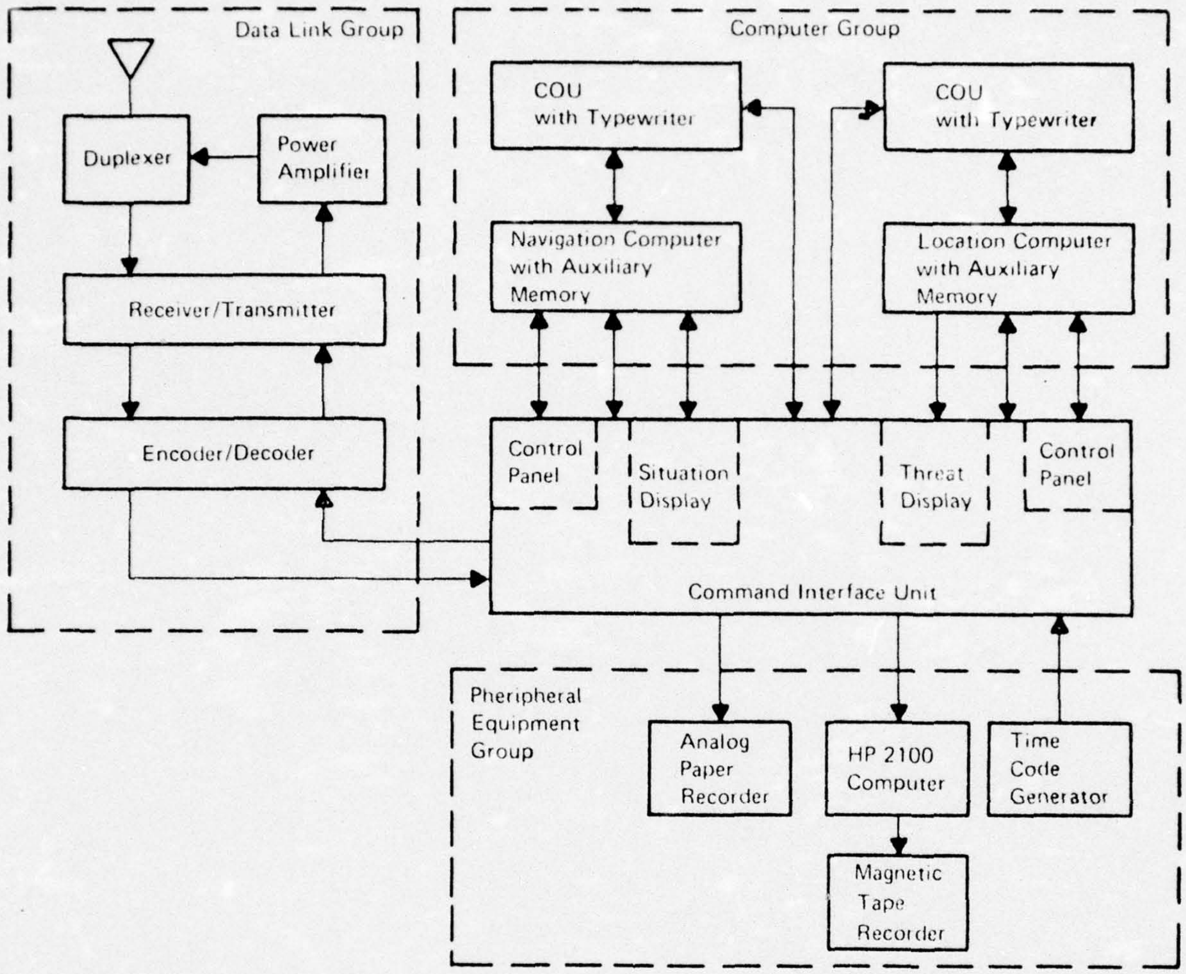

Figure 5-1 Ground Control Station Functional Block Diagram

Of the 10 functions, substantial changes are required for functions 1, 6 and 9. Relatively minor changes are required for functions 2, 4 and 7. The remaining functions remain essentially unchanged.

5.2 NAVIGATION COMPUTER PROGRAM STRUCTURE

The Navigation Computer Program structure divides the software functions into two execution categories. The first category consists of those functions which must be executed on a fixed time basis and are executed in the fast loop. The second category consists of those functions which may be updated on a time varying basis. This category of functions is executed in the slow loop. The Navigation Computer program structure is designed to operate on an interrupt basis. The interrupt occurs every 28.4 ms and is defined as the primary interrupt. The fast loop must be executed between each primary interrupt. When the primary interrupt occurs, slow loop status is saved and the fast loop functions are executed. Slow loop status is restored at the termination of fast loop execution and continues execution until the next primary interrupt occurs.

Different fast loop functions are performed in individual primary interrupt time slots according to a regular cycle repeated every 10 primary interrupts as follows:

Slots 1,2 and 3.... Airborne Relay Station Navigation
Slot 4.... DME Calibration for relay stations
Slots 5,7,9.... Navigation and Guidance for Weapon #1
Slots 6,8 and 10.... Navigation and Guidance for Weapon #2

The ALSS/WI software also includes provisions for a longer cycle capable of handling more weapons but this will not be used for the DME/SSM demonstration.

The fast loop execution sequencing is controlled by the Navigation Computer Executive and is illustrated in Figure 5-2. Encoding of uplink messages to communicate guidance commands and to initiate the range measurements and calibration operations required to perform navigation, is performed by uplink message preparation. Decoding of the downlink messages to obtain calibration values, range measurements, and status of the data links is performed by downlink message translation. Initial determination of weapon position is performed by Navigation Start (NS). Weapon control requires Weapon Execution, Navigation,

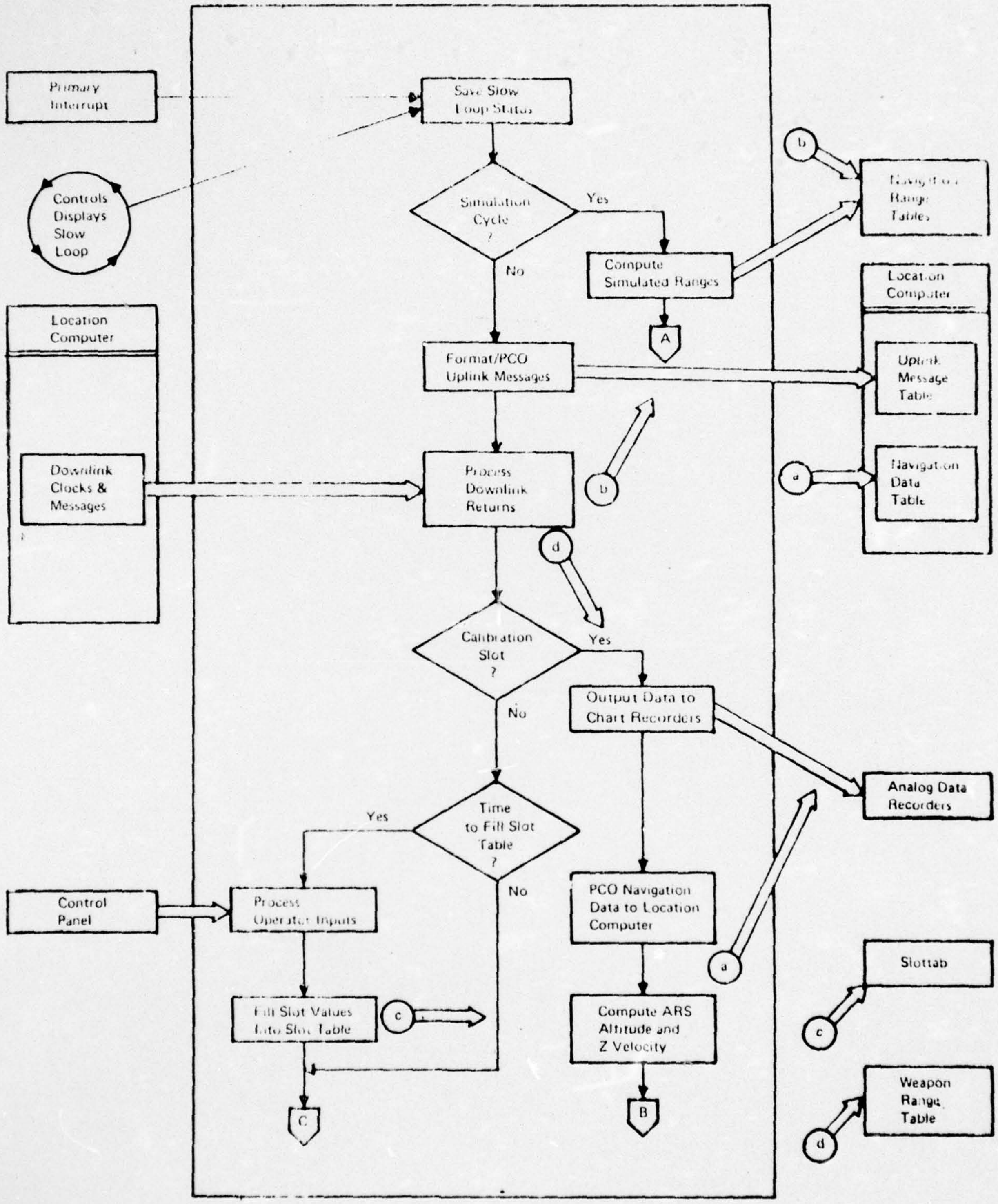

Figure 5-2 Navigation Computer Executive (Sheet 1 of 2)

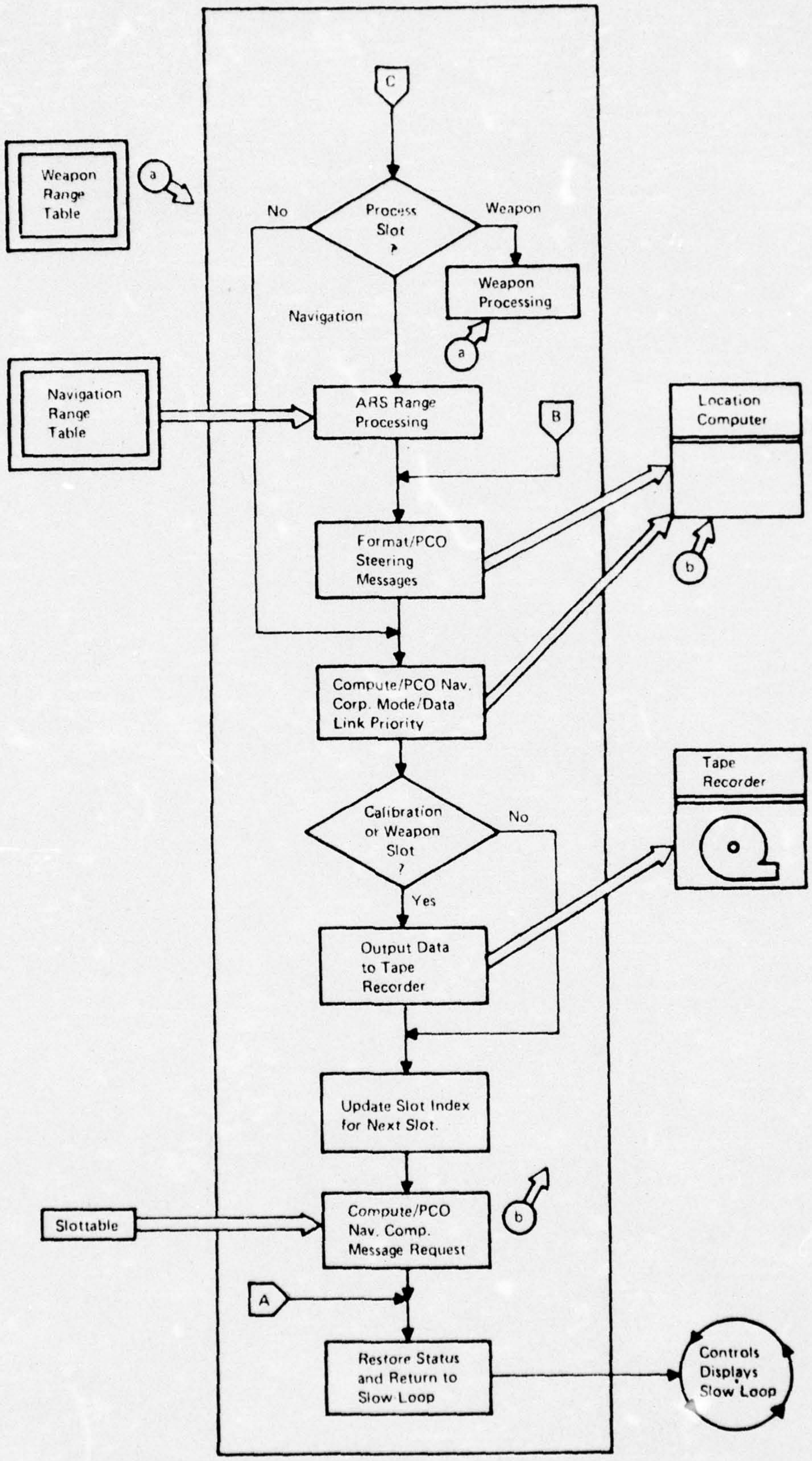

Figure 5-2 Navigation Computer Executive (Sheet 2 of 2)

and Guidance subroutines. A half-time (non-operational) Built-in-Simulation mode is provided for preflight tests where Built-in-Simulation is executed on alternate primary interrupt intervals. In this mode, Weapon Simulated Range routine and a Vehicle Model routine define simulated weapon ranges and vehicle response to data link commands.

The function of recording system status and performance data on the two Chart recorders is performed by the Chart Recorder routine. The Tape Recorder routine controls and formats the system status and performance data for the tape recorder.

The slow-loop execution sequencing is defined by several routines and is controlled by the Controls/Displays Executive. The display of present position indication of targets, ground and airborne relay stations, airborne relay station orbits, forward edge of battle area (FEBA), and the ground control station on the CRT is provided by the Controls/Displays CRT Driver. This routine also formats the system tabular display (to show ground station coordinates, airborne relay station parameters, and three different groups of target coordinates) and the fixed format display (to show system and weapon status, data link integrity, and debug core readout). Operator commands/requests provided by console switch settings and/or console keyboard inputs are interrogated and processed by Controls/Displays Operator action. Output of system performance data to the typewriter is performed by the Typewriter routine.

The Library subroutines provide commonly used routines for both the fast-loop and slow-loop functions. One important Library routine is the Time-Code-Generator routine. WSMR Range time is used to synchronize Greenwich Mean Time (Zulu time) with the navigation computer time.

5.3 WEAPON NAVIGATION AND GUIDANCE

Weapon processing requires the use of several weapon routines. Weapon navigation and guidance are under control of the Weapon Executive. Navigation and guidance are separated into their respective modules and are supported by special weapon subroutines.

The Weapon Executive controls the overall weapon software sequencing. A weapon cycle is divided into three iterations through the fast loop. For the ALSS/WI task, there was insufficient time to execute the total weapon processing task during a single primary interrupt interval. This same approach can be retained for SSM; however, the SSM task appears to be smaller in terms of complexity and execution time. Several simplifications are likely.

One area where simplification occurs is in the mode sequencing associated with different flight phases. DME/Hawk control consists of only three phases; preguidance, guidance, and blind guidance. As will be discussed later, a single guidance law is used throughout the guided flight phase.

Two navigation filters are being used for a single SSM. This can be accomplished by treating the SSM as two separate and distinct weapons or by requiring the weapon executive to control processing in two adjacent time slots as a result of activating a single weapon. The present approach is to define two separate SSMs. For example, the first SSM uses the two station plus altitude solution and is assigned a target. The second SSM uses the three station solution but no target is assigned. The first SSM will not be navigated until some fixed time following launch while the second SSM is navigated throughout. The weapon executive will determine the points at which navigation and then guidance begin for the first SSM.

The primary function of Weapon Navigation is to update position and velocity as a function of time. As a part of navigation, navigation filter gain constants must be generated. For ALSS/WI, they varied as a function of mission phase. For SSM, the filter constants will vary depending upon whether the two station plus altitude or three station solution is being used for navigation. The ALSS/WI also has a capability to use a three station plus altitude profile type of navigation. Because of the redundant measurement, this mode has a better reliability when one of the station ranges is intermittently missed. An altitude rate profile will be defined for the Hawk trajectory to provide a profile for threestation plus altitude method of navigation to supplement the three range solution when the weapon is at low altitude where altitude estimation accuracy is poor. A navigation start-up routine is required to start

the navigation filters. The present ALSS/WI algorithm will be used for the two range solution or to restart the three range solution after launch. Some minor changes will be made to the Nav Start ambiguity resolution logic to take into account apriori data regarding the expected direction of weapon flight.

The weapon guidance routine will require the most extensive changes because of the new guidance algorithm. However, a sizable number of equations can be salvaged as they are required to define the inputs to the guidance equations in each case. These include obtaining the position and velocity errors in down range (ED,$\dot{\text{ED}}$) and cross range (EC,$\dot{\text{EC}}$). Also, simulation analysis and preliminary stability analyses indicate that some form of compensation filter may be desired to process the commands developed by the basic guidance law described below. The existing filter algorithms and associated parameter scheduling routines may be adapted for this purpose.

A tangent guidance law has been identified by MICOM as the proposed guidance scheme for the DME/SSM demonstration program. This law generates an acceleration command by a combination of the position and velocity errors and is so named because an inverse tangent function is used in determining the contribution of the position error to the total acceleration command. The pitch/yaw acceleration commands are (PGO=pitch, YGO=yaw):

$$\text{PGO} = -\,\text{AX}\cdot\text{TAN}^{-1}(\text{BX}\cdot\text{ED}) - \text{GNXD}\cdot\left(\frac{|\dot{\text{ED}}| + \text{A}}{|\text{ED}| + \text{B}}\right)\cdot\dot{\text{ED}} - \text{BNZ}$$

$$\text{YGO} = -\text{AY}\cdot\text{TAN}^{-1}(\text{BY}\cdot\text{EC}) - \text{GNYD}\cdot\left(\frac{|\dot{\text{EC}}| + \text{A}}{|\text{EC}| + \text{B}}\right)\cdot\dot{\text{EC}} + \text{BNY}$$

The pitch and yaw acceleration commands must then be scaled before they can be transmitted over the data link.

The terms BNZ and BNY in the above expressions are bias commands corresponding to guidance line curvature. These can be computed using the existing curvature correction calculation algorithms. The remaining terms A,B, AX,BX etc, are selected by simulation analysis to provide a desired weapon trajectory

for a particular system geometry. Consequently, a single set of parameters will be expected to be used for the flight tests involving control from fixed ground stations. However, simulation results indicate that variations in these parameters are necessary for changes in system geometry such as will occur for the flight tests involving airborne relay stations. Further simulation study is required to quantify these parameter sensitivities and to define adaptive control algorithms which will adjust the guidance parameters as a function of system geometry. As a minimum, it is anticipated that the guidance software will be required to have distinct ground and airborne control modes, selectable by control panel inserts, to implement different guidance constants for the two different nominal system geometry cases.

DME guidance will be initiated shortly after the SSM passes the profile apex and will continue to a predetermined point at which blind guidance is initiated. From this point blind guidance normally guides the SSM to the target independent of DME control. Since there is no onboard blind guidance processor for the demonstration, the commands will be generated by the navigation computer and transmitted to the SSM to simulate blind guidance.

The final selection of the blind guidance implementation is still under investigation by MICOM. Reference 5-3 presents the results of a preliminary analysis of the following technique which has been recommended for consideration and evaluation.

1. Bias commands for guidance line curvature correction would be communicated to the weapon as distinct values by one message prior to or during guidance initiation.

2. Dynamic increments representing the difference between the bias command and the total required command are communicated for each guidance updated cycle. As long as the data links are operating, these dynamic increments are added to the bias values in an onboard processor to form the total command supplied to the autopilot.

Reference 5-3 "Blind Guidance Math Flow for DME/HAWK Simulation," IBM Report No. 76-L61-016, IBM, Owego, NY, 1 September 1976

3. The onboard processor would also calculate an average value for the magnitude (and possible rate of change) of the dynamic command increments.

4. When the data links are disrupted, the dynamic command increment is set equal to the accumulated average value and then decayed to zero over a period of time representing nominal vehicle response characteristics.

As previously mentioned, this technique cannot be tested directly during the demonstration flight test because the WGSS does not have the necessary onboard processing capability. However, the functional concept will be demonstrated by including in the ground based navigation computer software a blind guidance processor simulation routine which will function in the same manner as would an onboard processor. Figure 5-3 illustrates a simple command filtering algorithm for simulated blind guidance. DME ranging operations will be inhibited at a selected blind guidance altitude. The constant DIKA controls the amount of smoothing applied to commands when the data links are in. DOKA controls the rate at which commands decay to the bias after data link disruption. Uplink data link communication will be maintained until impact to communicate the simulated blind guidance commands to the weapon. The criterion for initiating blind guidance will probably be the altitude estimate developed in the parallel 3 range navigation solution. However, provisions can be incorporated to allow manual override of this automatic criterion by an operator insert from the control panel.

5.4 BUILT-IN-SIMULATION

Built-in-Simulation (BIS) provides an software model of the dynamics of the ARS and SSM vehicles and of the DME range measurements. This permits a realistic verification of the software and provides a tool useful for analysis and pre-mission testing. The ARS simulation routines will not change except for numerical data defining the orbits to be used for the demonstration.

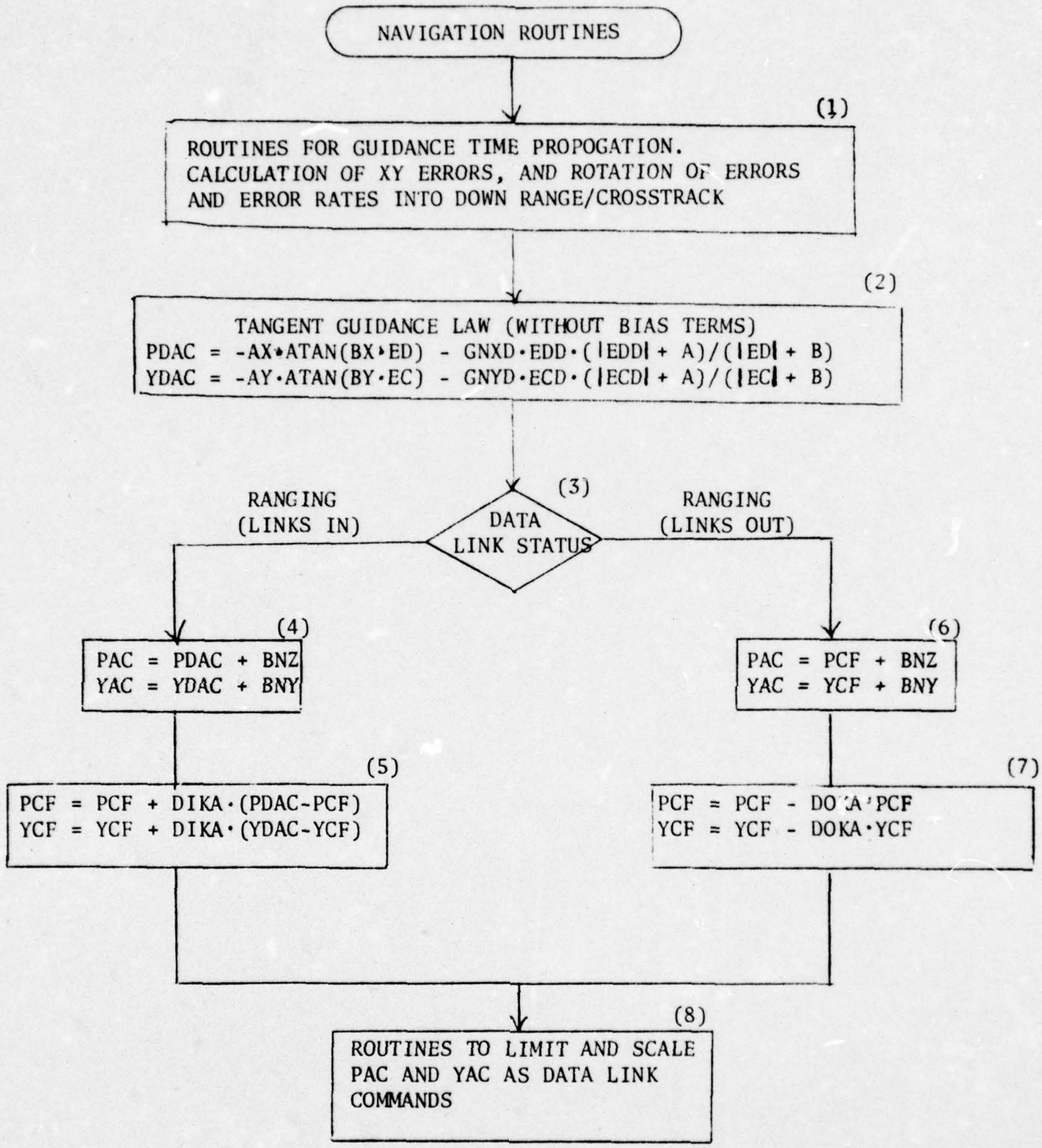

Figure 5-3 Guidance Math Flow for Simulated Blind Guidance

In BIS mode, primary interrupts (28.4 millisecond intervals) for simulation alternate with primary interrupts for normal operation. Since only hlaf of the intervals are used for the operational program, simulation is at a half-time rate. Figure 5-4 shows the interface between the operation program and Built-in-Simulation. The outputs from BIS are simulated range measurements. They replace the DME derived ranges. Navigation and Guidance equations are processed during the operational program interval and they result in guidance (acceleration) commands. The acceleration commands are the inputs to BIS. The interface is seen to be very simple; namely, simulated ranges and acceleration commands.

A SSM range routine provides the required weapon to relay station ranges. Simulated noise and round-off errors can be selected in preference to idealized inputs. It is also possible to simulate data link dropouts between the weapon and relay stations. The dropout conditions are controlled via the control panel. The operator can initiate and terminate a condition by selecting links to have outages or the operator can request a prestored outage condition.

The Autopilot and Vehicle Dynamics models provide state vector information (e.g. position, velocity) for a single vehicle during the mission phases. The first mission phase is concerned with the time from launch to the point where DME guidance starts. During this period the DME commands are zero and a simple model is used to generate the state vector as a function of time. When DME guidance takes over, more complicated but still simple autopilot and vehicle dynamics models are used to describe the response to the guidance commands.

The SSM autopilot and vehicle dynamics models are the areas where the majority of changes are necessary to the existing Built-in-Simulation program. Reference 5-4 presents the results of a preliminary analysis which establishes a modified autopilot model and aerodynamic lift and drag polynomials which will provide a sufficiently accurate approximation to Hawk vehicle performance characteristics. Reference 5-4 also presents simple acceleration models which will approximate vehicle motion during the boost and sustain

Reference 5-4 "Preliminary Definition of DME/Hawk Built-In-Simulation," IBM Report No. 76-L61-019, IBM, Owego, NY, 15 October 1976.

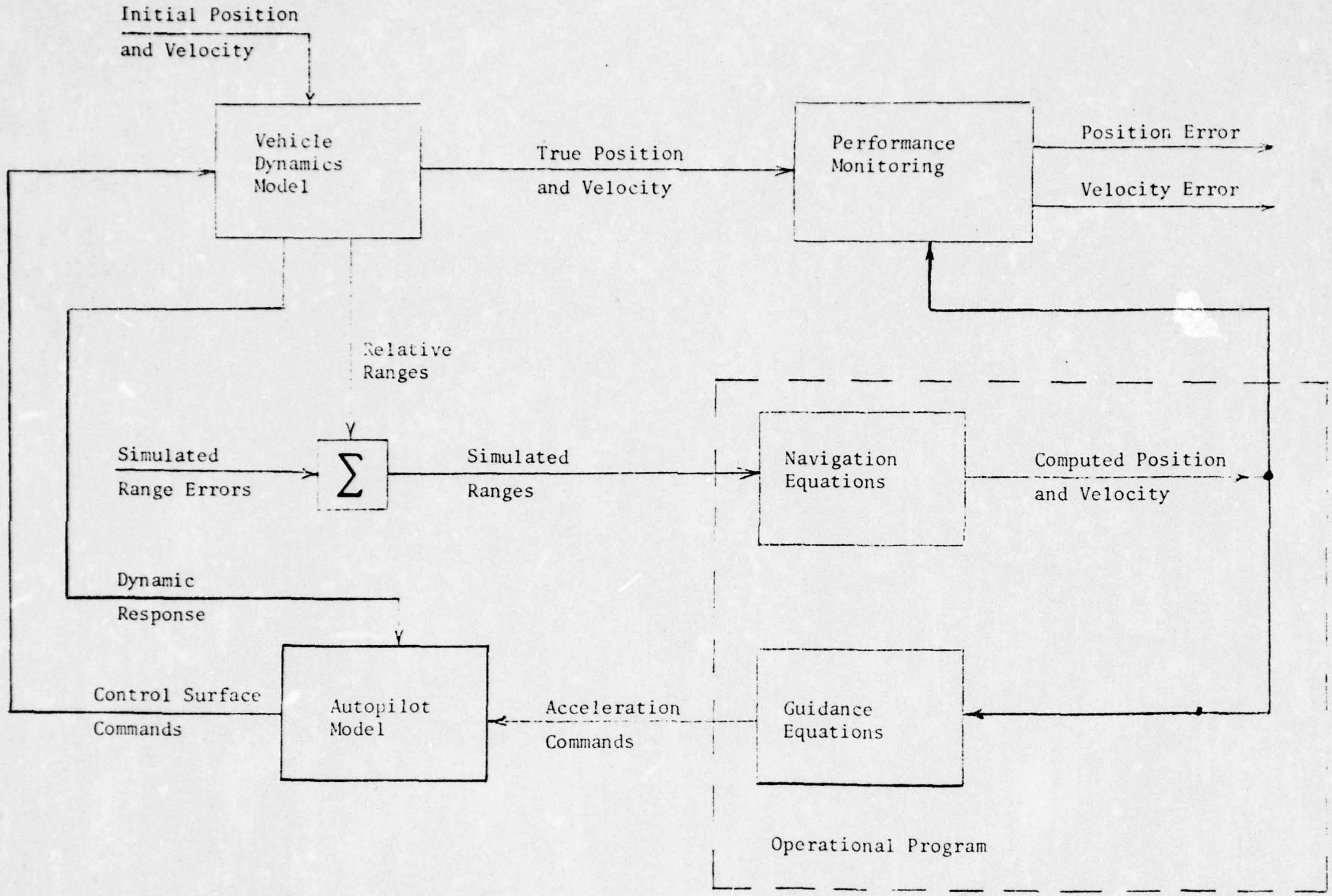

Figure 5-4 Simulation/Operational Program Interface

powered flight phases. Further analysis is required to complete validation of these preliminary models, by comparison to 6-DOF simulation results. Also, minor changes to the BIS logic must be defined to control BIS initialization and to assure proper interface with the operational program functions. Other aspects of BIS including performance monitoring remain unchanged from the basic ALSS/WI software.

5.5 DATA RECORDING ROUTINES

Data recording is accomplished using three different types of peripherals namely Chart recorder (strip chart), tape recorder, and typewriter.

5.5.1 Typewriter Output Routine

The typewriter is normally used for real-time hard copy printout of the expected x and y miss distances at weapon impact, indicated by loss of DME data links. For the SSM demonstration this will be expanded to include output of error at the point where simulated blind guidance is initiated.

5.5.2 Chart Reorder Routine

The Chart recorder routine provides the capability to drive two recorders of eight channels each by supplying various types of data in a form suitable scaled for recording. One recorder also has four event markers; one event marker is normally used to record time.

The primary functions of the Chart recorder routine are

1. To check the operator requested formats to ensure their validity.
2. To extract data from an intermediate buffer, perform bias, scaling, and formatting operations and insert the data into second intermediate buffer.
3. To initiate output of the data
4. To perform calibration of each Chart recorder if no other format has been requested for it. There are presently 6 other formats.

The changes to the chart recorder routine are those required for the output of new variables. This impacts chart recorder function #2.

5.5.3 Digital Data Recording (Tape Recording) Routine

Post flight data reduction and analysis are made possible by the continual recording of key system variables in the HP2100. This function replaces the original tape recorder function. Data is recorded on the HP2100 peripheral tape unit for quick look and in the event merging data with range instrumentation is desired.

For the SSM demonstration, navigation computer software modifications will include additions/deletions of variables in recorded output data. These changes are anticipated to primarily affect variables recorded in the weapon navigation/ guidance Tape Recorder ID (TRID) 20 data block. Depending upon the extent of TRID 20 changes, it may be desirable to assign a new TRID number for the revised TRID 20.

Modifications must be made to the Tape Recording routine to record DME missile commands, suitable for input to the DME/Hawk simulation at MICOM for comparison of post flight simulation results with actual flight records. Although commands are presently included in the TRID 20 data, the recording rates relative to uplink command rates are such that TRID 20 data contains only about every third command. Therefore, to record all commands, changes will be made such that commands are buffered in the CP-2 and output to tape in a special TRID. This will require modifications to the HP2100 data reduction software routines to output the special TRID and format the command data.

5.6 DISPLAY AND CONTROL PANEL ROUTINES

The existing ALSS/WI display capability requires changes for SSM. Symbols presently exist for WGSS, ground stations and targets. There is an outline (FEBA) generated by 7 contiguous line segments which can be used to represent a range safety corridor. With a minor modification, the number of line segments will be increased for finer detail.

A special range safety display will be implemented by Navigation computer software and transferred to the Location computer for display. Both a vertical profile and a horizontal profile can be represented. They would occupy the upper and lower halves of the display respectively, as illustrated by the preliminary concept depicted on Figure 5.5.

The vertical profile indicates SSM altitude relative to a nominal altitude profile as a function of down range distance. The horizontal profile indicates cross range error as a function of down range distance. The target is represented as T, the launch point by a 0, and the SSM by a Δ. Emanating from the Δ is a vector defining the direction of the velocity vector.

Range safety boundaries are indicated on the horizontal profile. Also indicated on the horizontal profile are the locations of the ground stations and other landmarks pertinent to range safety. Ground stations are indicated by G's with numerical subscripts, landmarks by special symbols ($\square$). A vertical bar indicates the range for expected DME guidance take-over.

Two spare switch positions on the ALSS/WI control require definition for SSM. One switch position will be used for launch initiate. A voice count down indicates launch to the GCS operator who in turn enters the launch initiate to synchronize the computer. A second switch position is used for a new prelaunch weapon checkout routine which will verify proper operation of the SSM prior to launch. Special data link messages are selected by control panel inputs and transmitted to the SSM. The weapon response will be observed and verified as being correct.

5.7 NAVIGATION COMPUTER PROGRAM SIZE & COMPLEXITY

The ALSS/WI software serves as the base from which to develop the SSM software. The current program size is indicated in Table 5-1. There are approximately 2000 spare core locations available. There are also about 2850 locations in the Weapon module, and 750 locations in Built-in-Simulation which will be replaced for SSM. This amounts to 5600 core locations. The SSM modifications are expected to require approximately 1000 locations in the weapon module, 750 in the Built-in-Simulation module, and 250 for minor changes in other modules. Approximately 3600 locations remain and should be adequate for the range safety display generation and transfer.

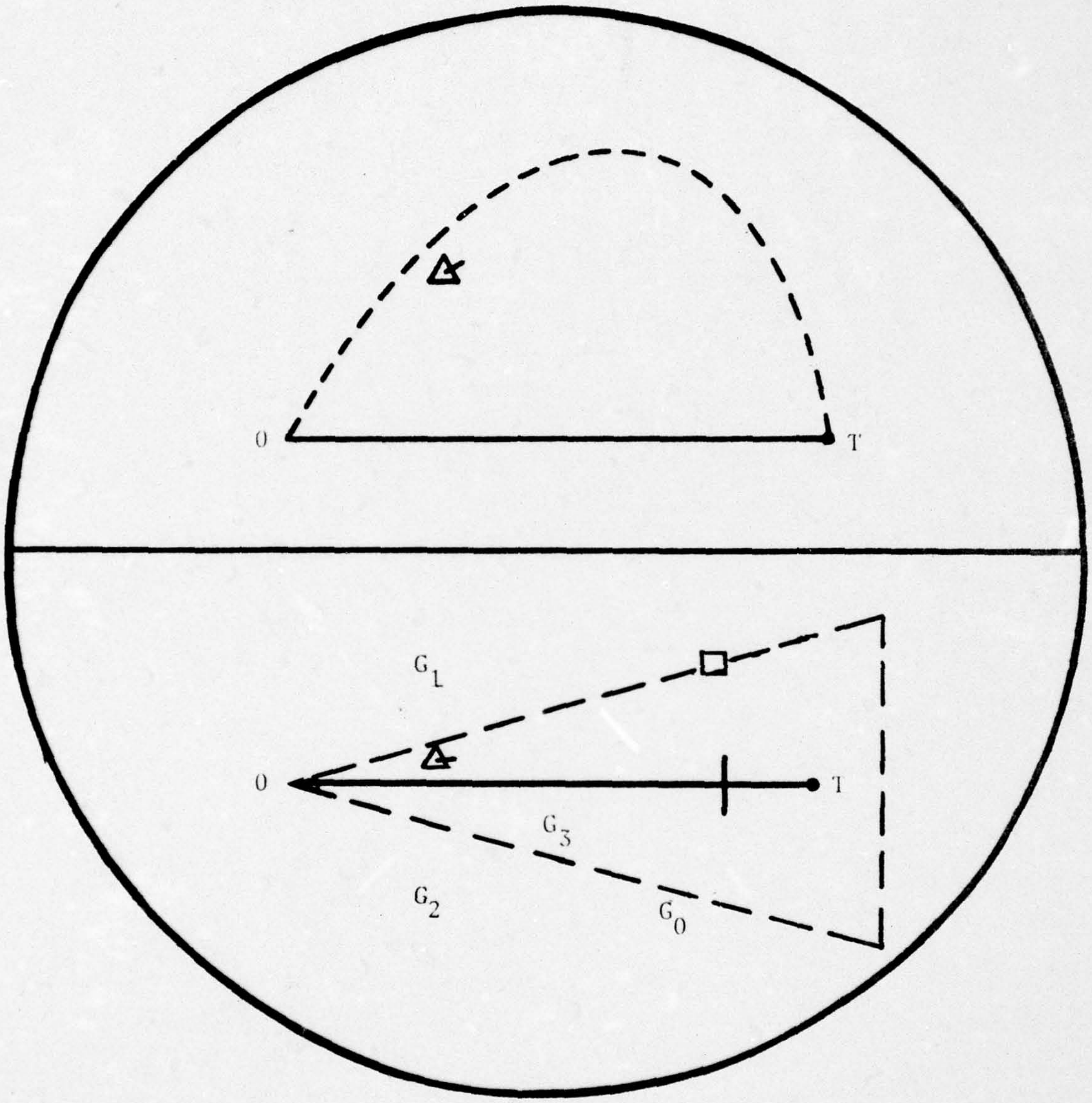

Figure 5-5 Range Safety Display Concept

The basic execution sequence will not be changed from ALSS/WI. Use of the 10 primary interrupt navigation and guidance cycle results in a guidance command update rate of approximately 10 times per second. The fast loop computations for SSM are slightly less complex than those for GBU-15, so no problems are anticipated in completing these calculation in the alloted time.

Table 5-1 ALSS/WI Navigation Computer Storage Requirements

Function	Storage
Control Panel/Displays	9860
Executive	1720
Data Link	2268
Navigation Start-up	1008
ARS Navigation	3414
Weapons	6310
Recorder	2478
Library	618
Built-in-Simulation	2102
Test	974
Total	30742
Spare	2026

6.0 REFERENCES

1-1 "DME-Basic Hawk Missile Analysis-Final Report for Period 1 July 1976-30 October 1976," IBM Report Number F18-76-H02, IBM, Huntsville, Alabama, October 1976

2-1 "WGSS-SSM Subsystem Design and Performance Goals", IBM No. 76-L61-018, IBM, Owego, NY, 15 October 1976

2-2 "WGSS SSM Acceptance Test Procedures", IBM No. 76-A64-004, IBM, Owego, NY, 15 October 1976

4-1 "Preliminary DME Navigation Accuracy Analysis for DME/SSM Demonstration Flight Tests," IBM CD-3-76-0183, IBM, Owego, New York. October 1976 (Secret)

5-1 "Final Report for Weapon Integration Program - Vol. III - Software Functional Description," IBM Report No. 76-M55-004, IBM, Owego, NY, 2 April 1976

5-2 "Weapon Integration Program Software Contract End Item Detailed Technical Description (Part II) Operation Program," IBM Spec. No. 6007882, IBM, Owego, NY, 31 January 1976

5-3 "Blind Guidance Math Flow for DME/HAWK Simulation," IBM Report No. 76-L61-016, IBM, Owego, NY, 1 September 1976

5-4 "Preliminary Definition of DME/HAWK Built-in-Simulation," IBM Report No. 76-L6-019, IBM, Owego, NY, 15 October 1976.

APPENDIX A

DME ANTENNA PATTERNS

(GROUND GUIDANCE)

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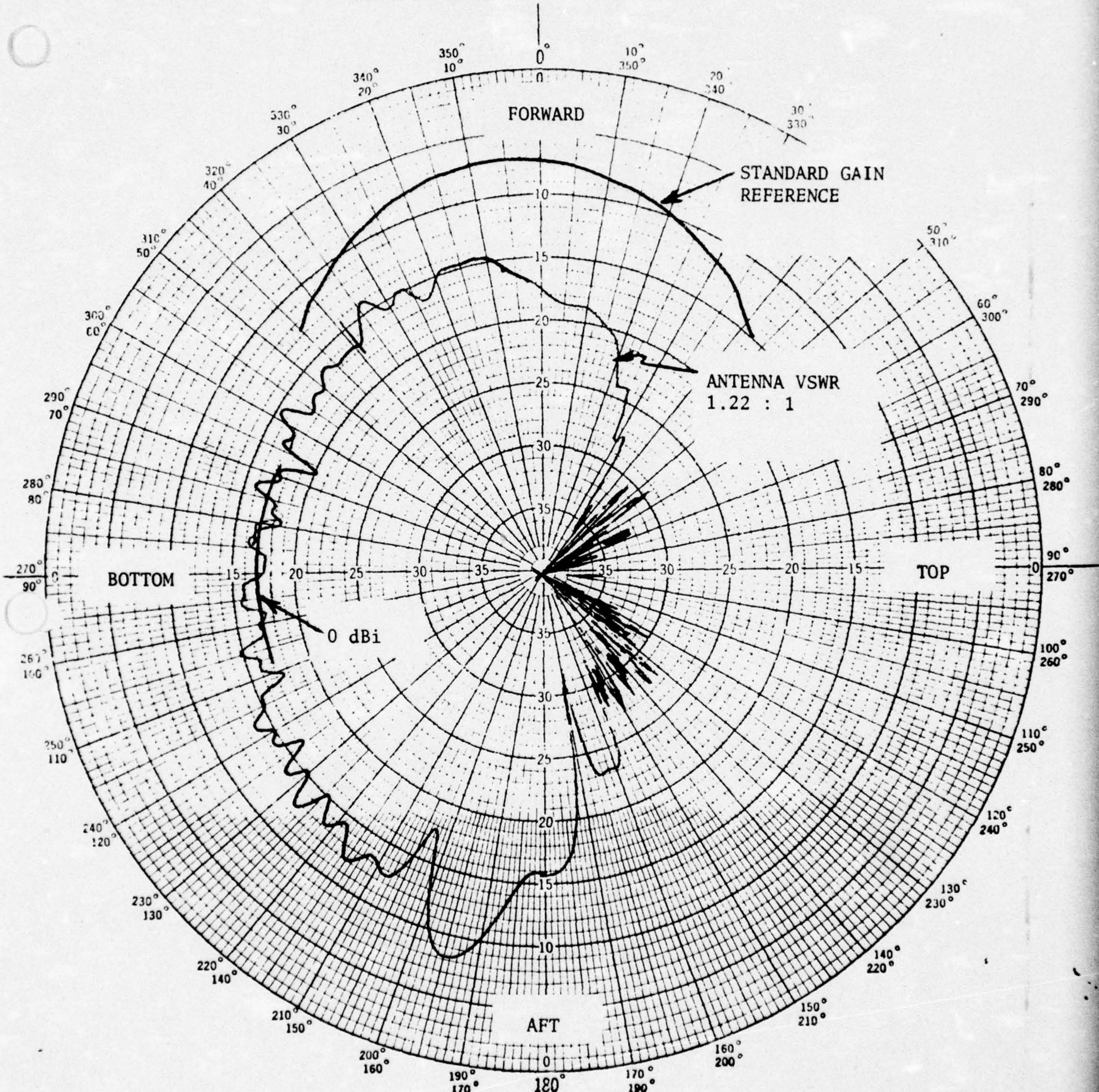

Date 7/9/76 Chamber No. 2
Project Frequency 4Fo Pattern Number 1
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: —— H POL. METAL NOSE CONE PITCH PLANE

FIGURE A-1

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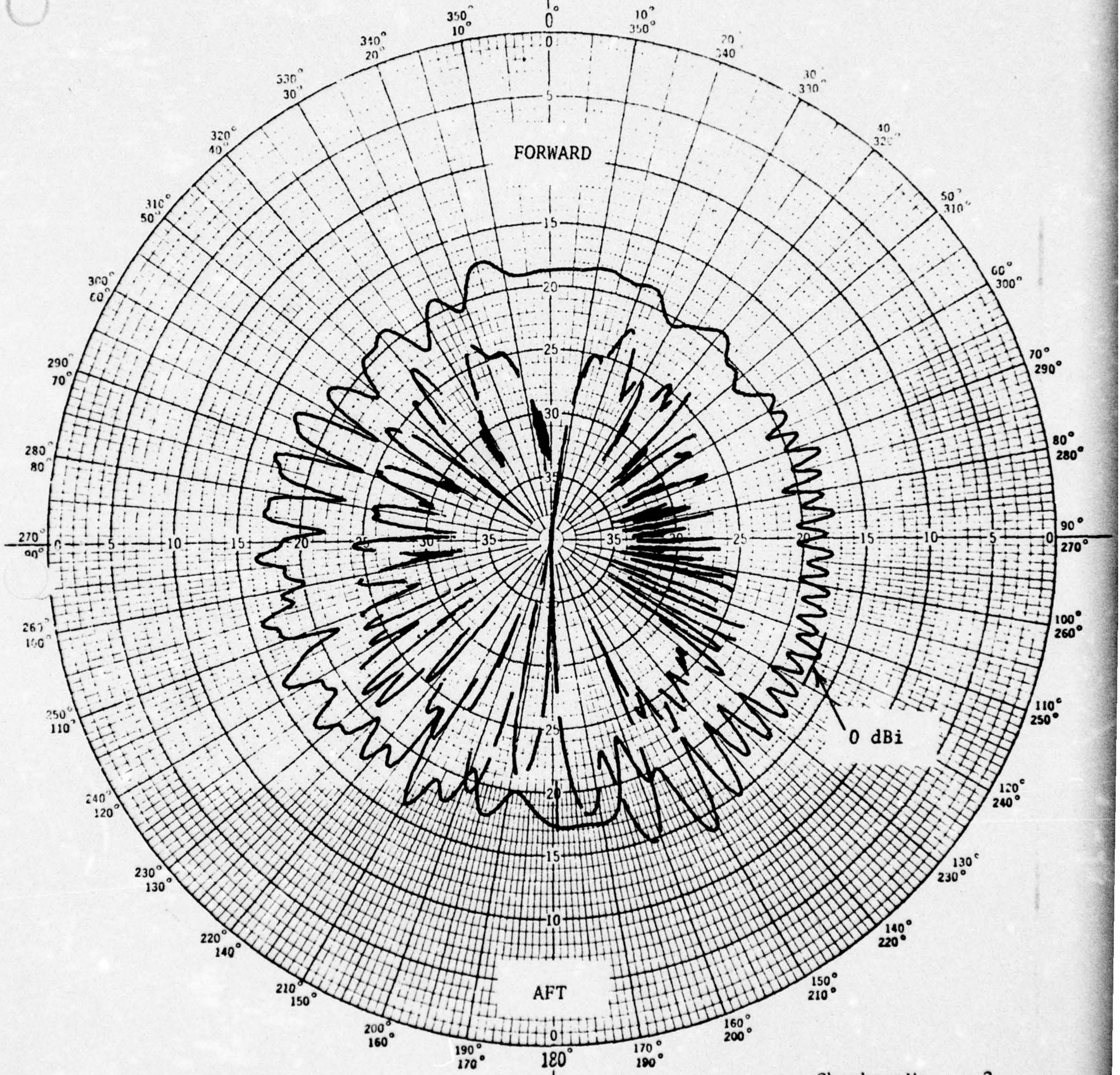
ANTENNA APPLICATIONS LABORATORY



Date 7/9/76 Chamber No. 2
Project Frequency 4Fo Pattern Number 2
0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power
Transmitter Polarization: Vertical Horizontal Rotating Linear Circular
Test Sample Scale & Model
Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)
Remarks:
——— V POL. METAL NOSE CONE YAW PLANE - 0° NOSE ELEVATION
----- H POL.

FIGURE A-2

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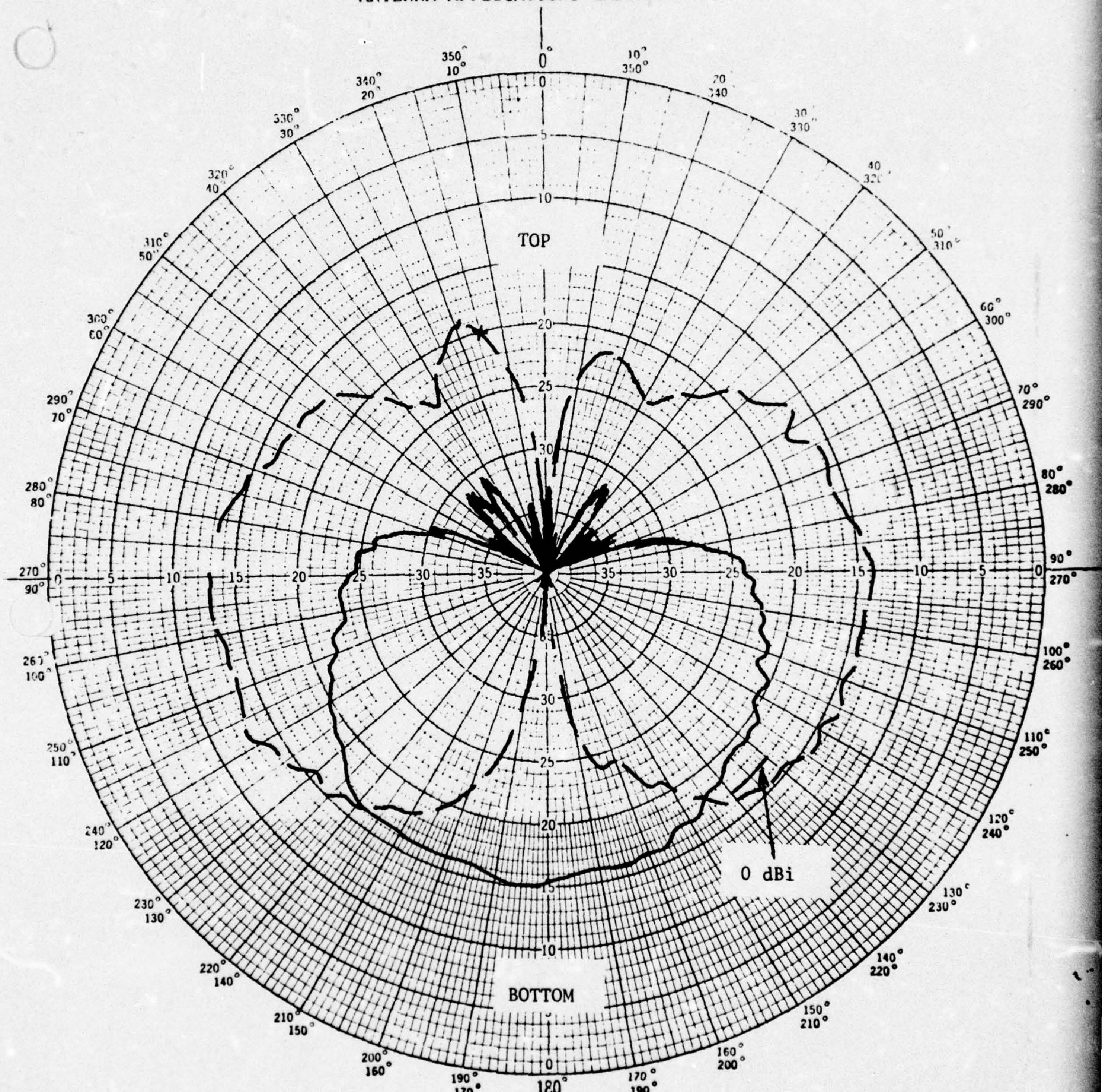
ANTENNA APPLICATIONS LABORATORY



Date 7/12/76 Chamber No. 2

Project ______ Frequency 4Fo Pattern Number 14

0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: ——— V POL. METAL NOSE CONE ROLL PLANE - 90° NOSE DEPRESSION

----- H POL.

FIGURE A-3

IBM CORPORATION
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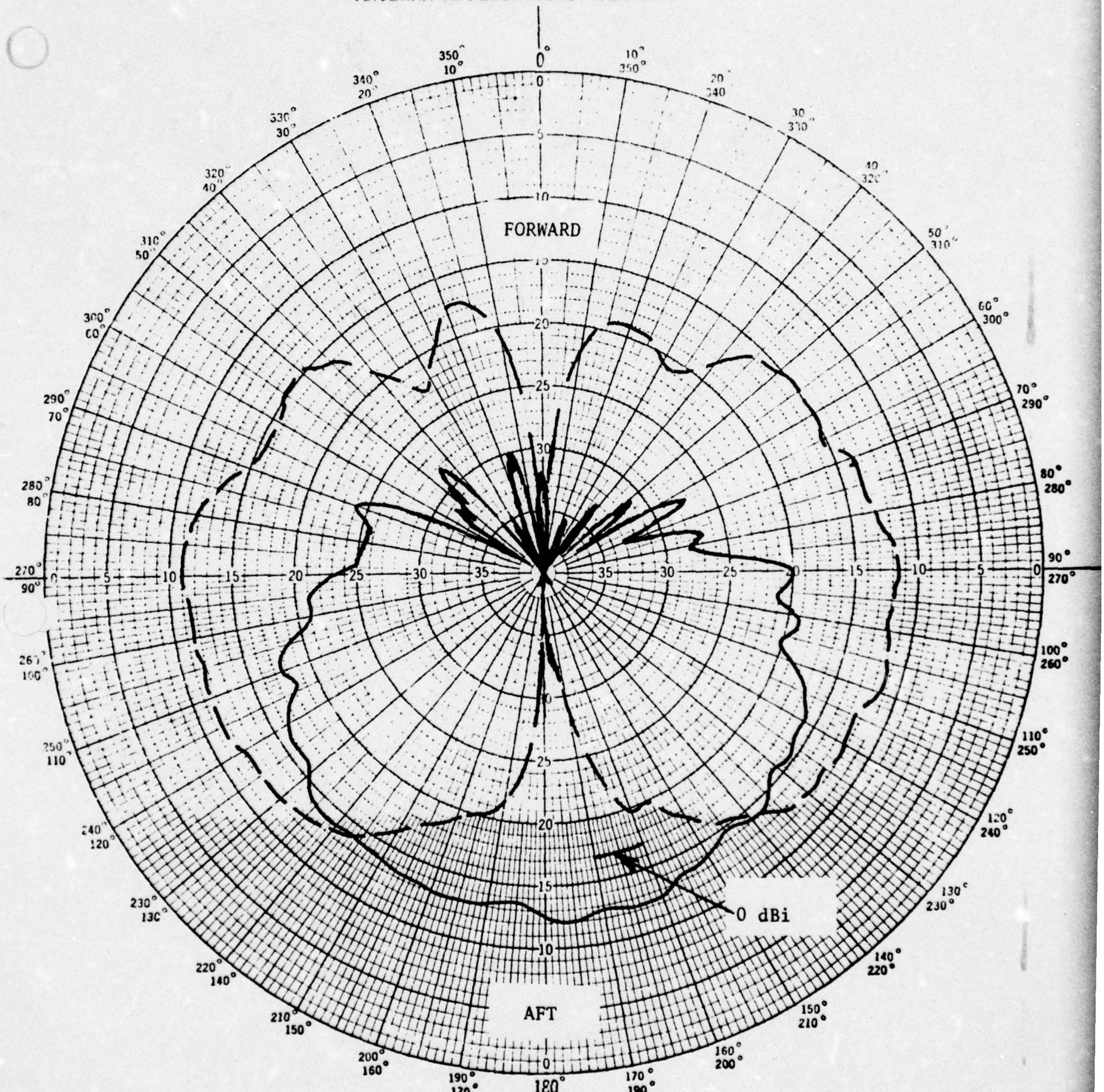
ANTENNA APPLICATIONS LABORATORY



Date 7/12/76 Chamber No. 2
Project ____ Frequency 4 Fo Pattern Number 13
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: —— V POL. METAL NOSE CONE 75° NOSE DEPRESSION
---- H POL.

FIGURE A-4

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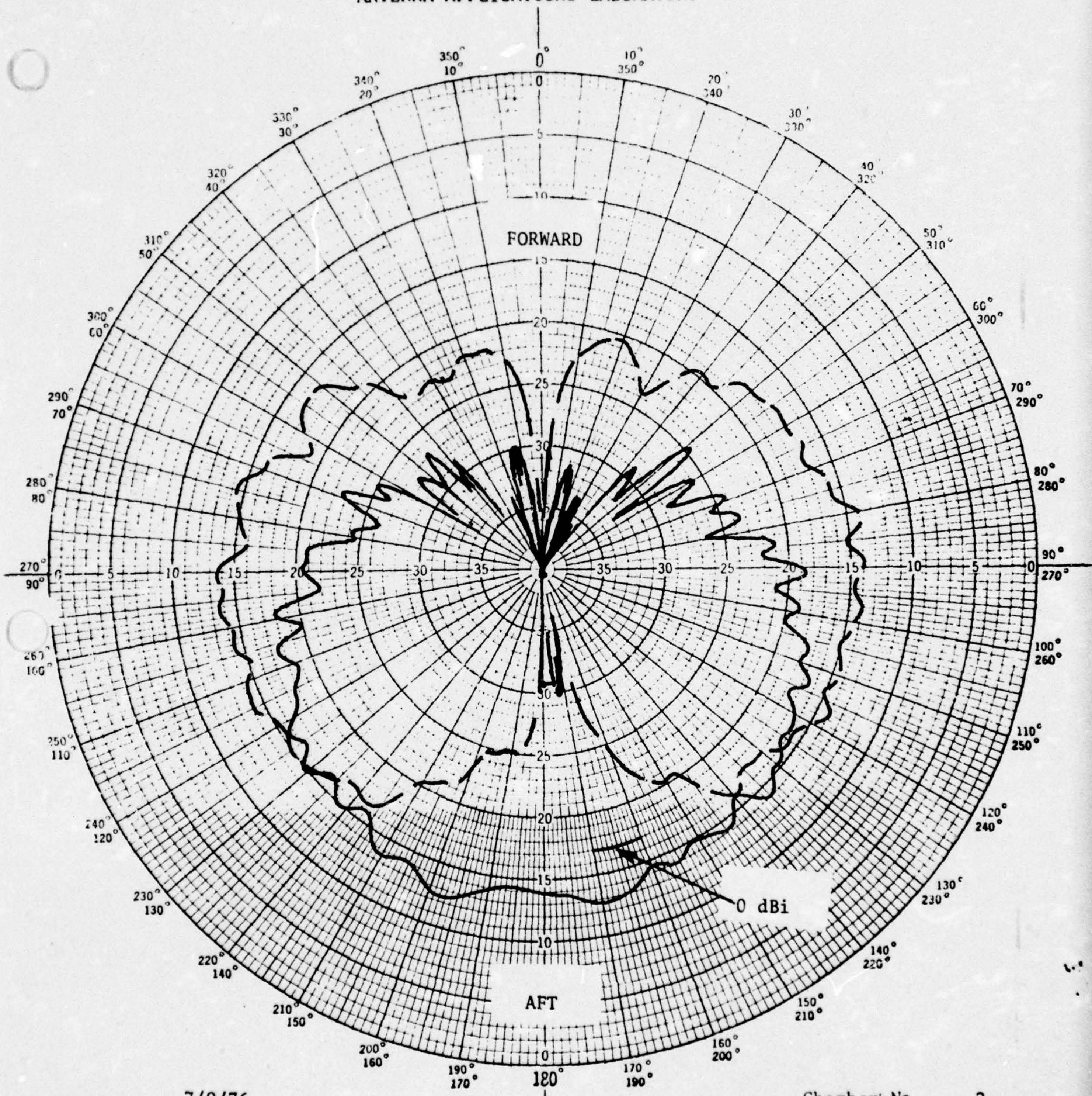
ANTENNA APPLICATIONS LABORATORY



Date 7/9/76 Chamber No. 2
Project ______ Frequency 4 Fo Pattern Number 4
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ______ Scale & Model ______
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks:

—— V POL. METAL NOSE CONE 60° NOSE DEPRESSION

---- H POL.

FIGURE A-5

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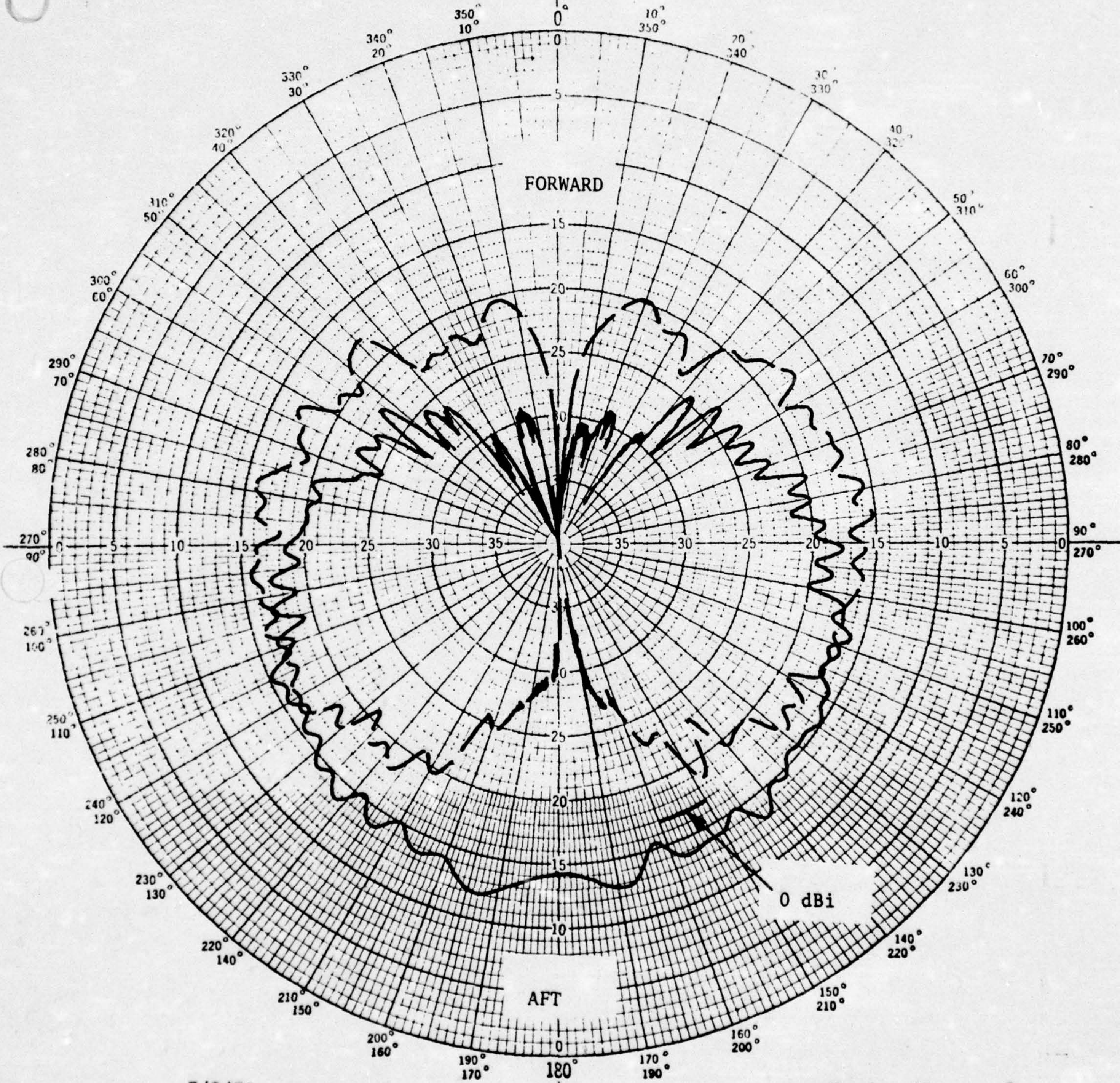
ANTENNA APPLICATIONS LABORATORY



Date 7/9/76 Chamber No. 2

Project Frequency 4 Fo Pattern Number 8

0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power

Transmitter Polarization: Vertical Horizontal Rotating Linear Circular

Test Sample Scale & Model

Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)

Remarks: ——— V POL. METAL NOSE CONE 45° NOSE DEPRESSION

----- H POL.

FIGURE A-6

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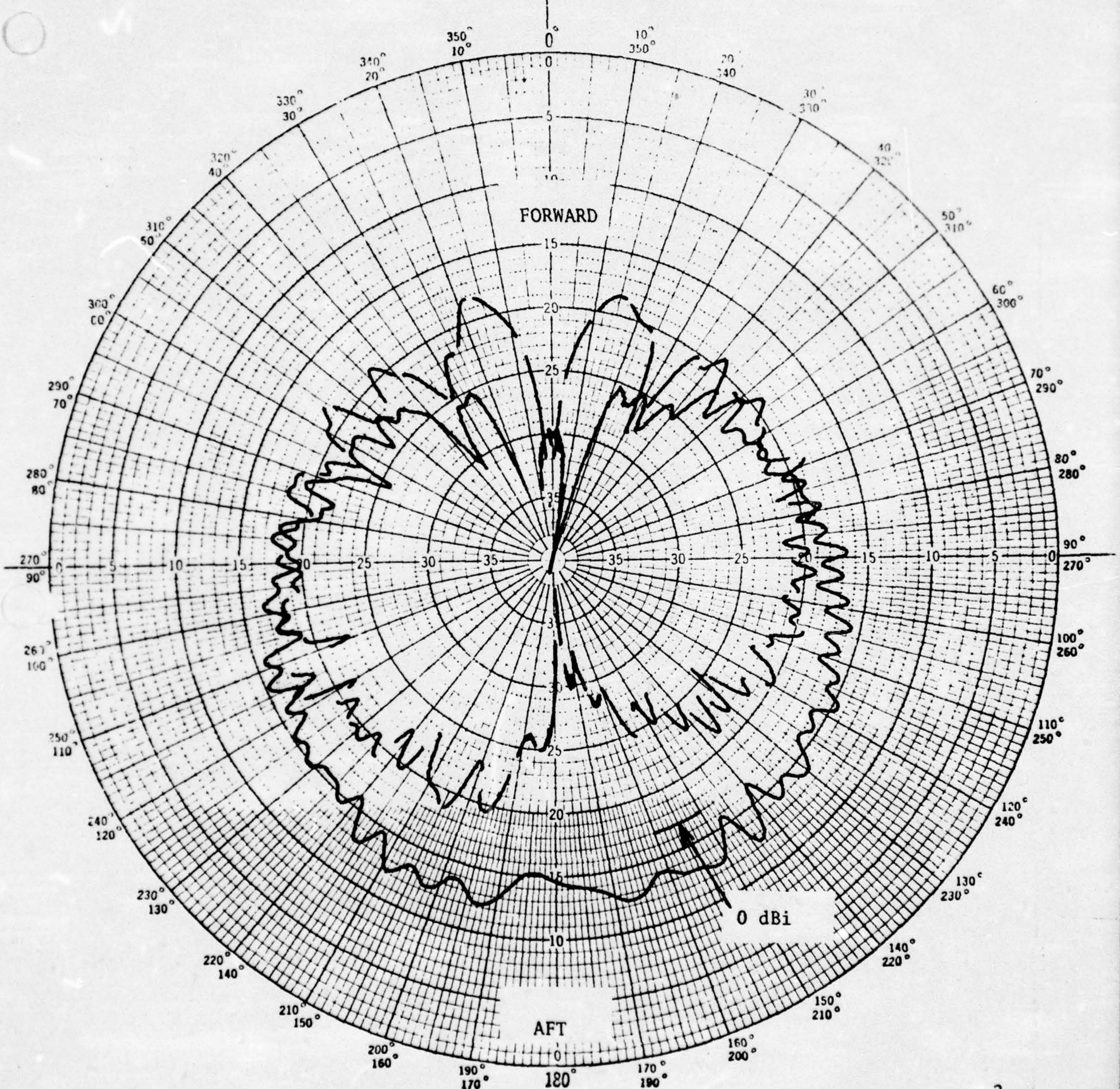
ANTENNA APPLICATIONS LABORATORY



Date 7/9/76 Chamber No. 2

Project Frequency 4 Fo Pattern Number 5

0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power

Transmitter Polarization: Vertical Horizontal Rotating Linear Circular

Test Sample Scale & Model

Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)

Remarks: —— V POL. METAL NOSE CONE 30^{o} NOSE DEPRESSION

---- H POL.

FIGURE A-7

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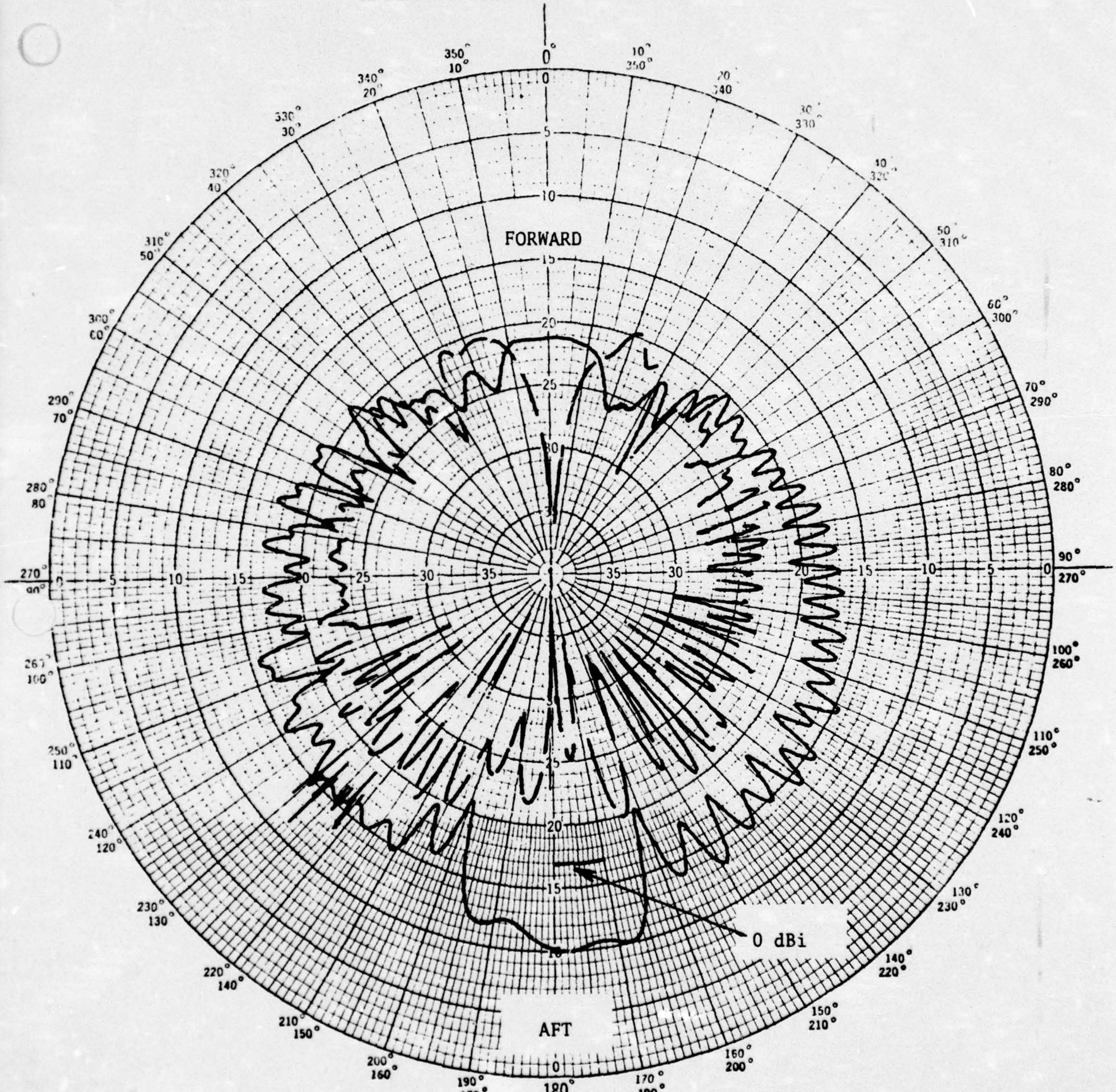

Date 7/9/76 Chamber No. 2
Project ______ Frequency 4 Fo Pattern Number 4
0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ___ Linear (dB) ___ Power ___
Transmitter Polarization: Vertical ___ Horizontal ___ Rotating Linear ___ Circular ___
Test Sample ______ Scale & Model ______
Test Sample Polarization: Vertical ___ Horizontal ___ Circular (L-H) ___ (R-H) ___
Remarks: ——— V POL. METAL NOSE CONE 15° NOSE DEPRESSION
----- H POL.

FIGURE A-8

APPENDIX B

DME ANTENNA PATTERNS

(PRS FLIGHTS)

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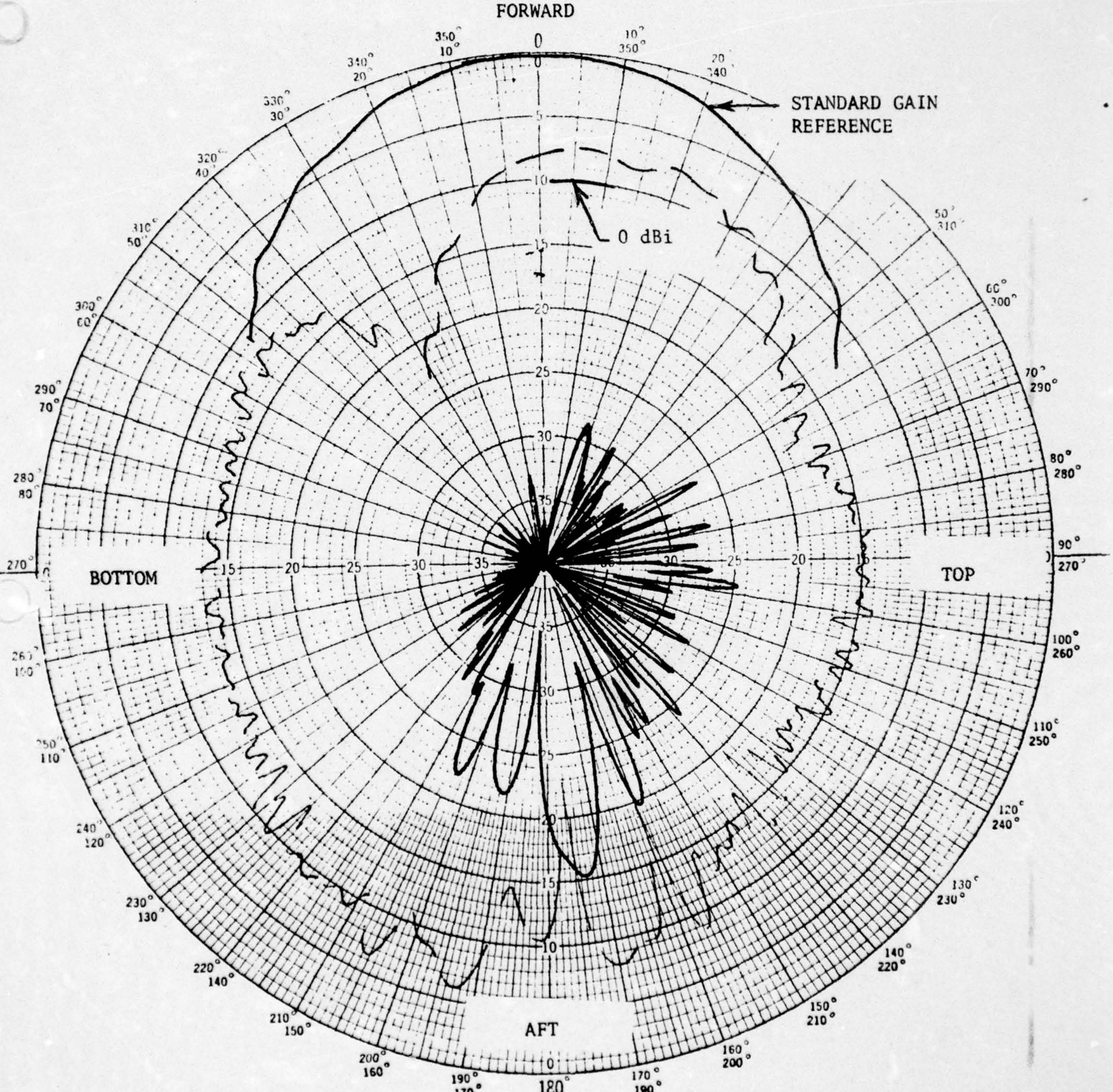

Date 8/17/76 Chamber No. 2

Project ______ Frequency 4Fo Pattern Number 1

0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ___ Linear (dB) ___ Power ___

Transmitter Polarization: Vertical ___ Horizontal ___ Rotating Linear ___ Circular ___

Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ___ Horizontal ___ Circular (L-H) ___ (R-H) ___

Remarks:
—— V POL. DME ANTENNA PAIR PITCH PLANE 180° PHASE DIFF.
---- H POL.

FIGURE B-1

IBM CORPORATION
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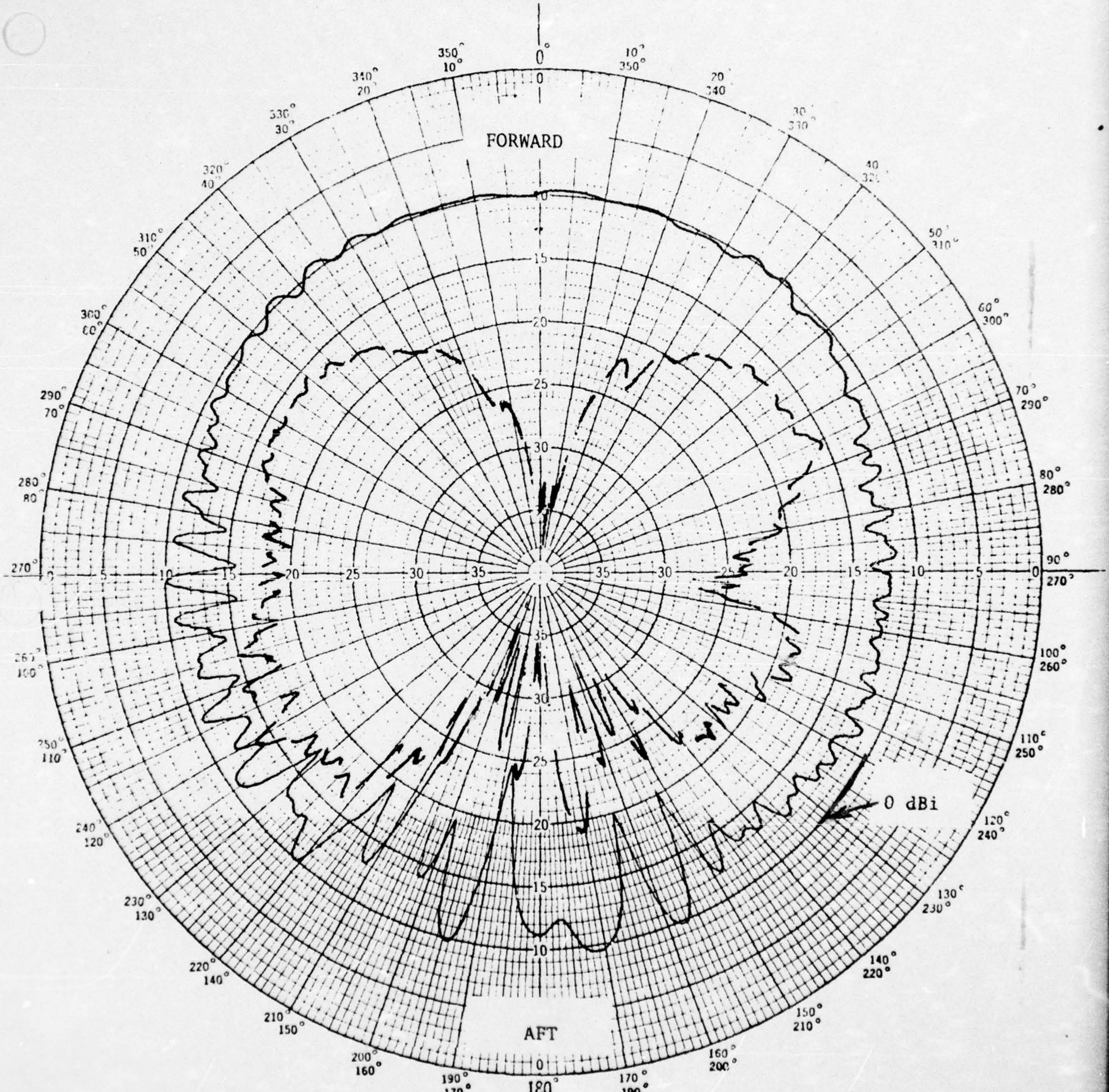

Date 8/17/76 Chamber No. 2
Project Frequency 4Fo Pattern Number 2
0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power
Transmitter Polarization: Vertical Horizontal Rotating Linear Circular
Test Sample Scale & Model
Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)
Remarks: —— V POL. DME ANTENNA PAIR YAW PLANE
---- H POL. 0° NOSE ELEVATION

FIGURE B-2

IBM CORPORATION
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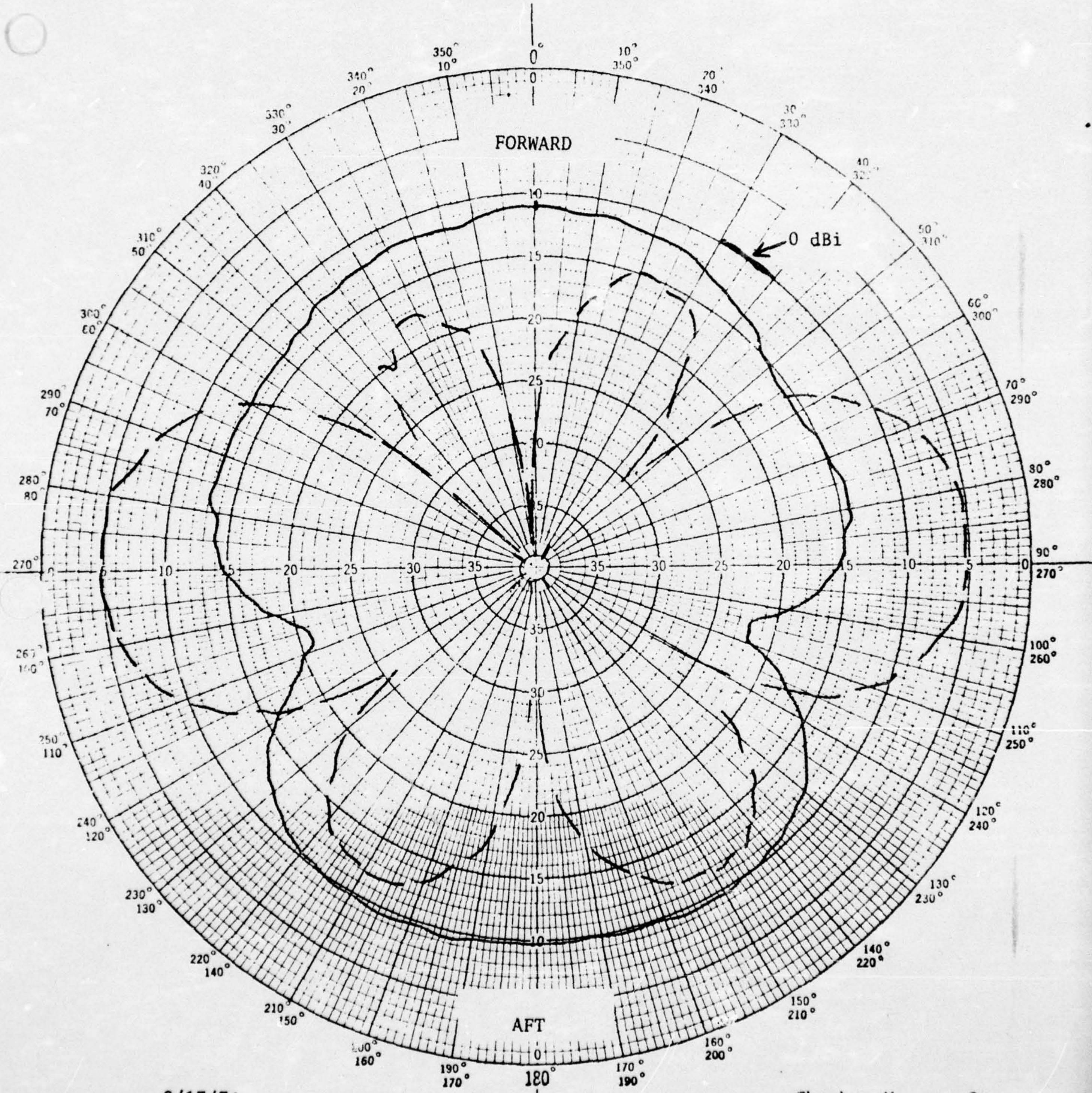
ANTENNA APPLICATIONS LABORATORY



Date 8/17/76 Chamber No. 2

Project Frequency 4Fo Pattern Number 3

0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power

Transmitter Polarization: Vertical Horizontal Rotating Linear Circular

Test Sample Scale & Model

Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)

Remarks: —— V POL. DME ANTENNA PAIR ROLL PLANE

------ H POL. 90° NOSE ELEVATION

FIGURE B-3

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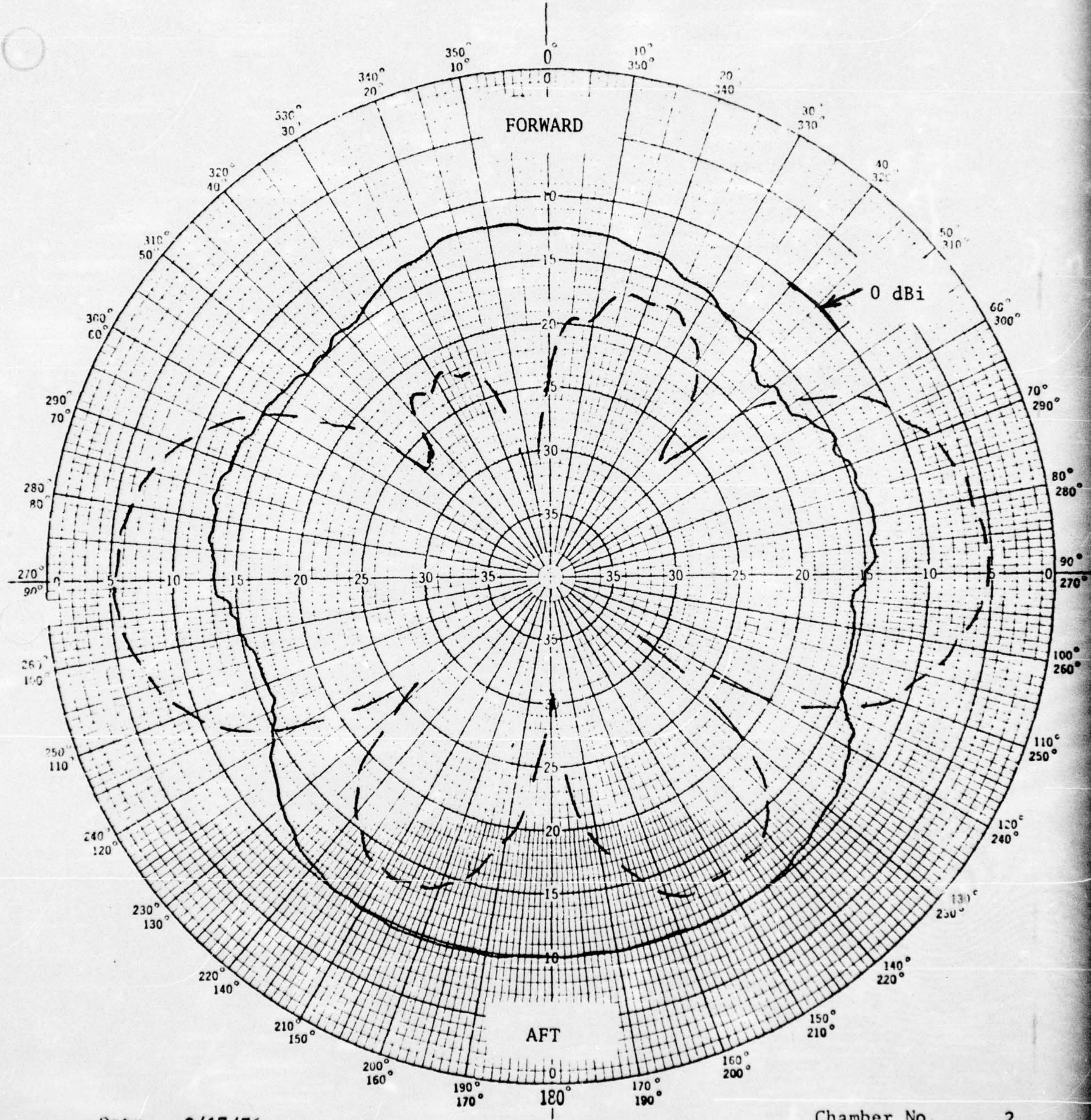
ANTENNA APPLICATIONS LABORATORY



Date 8/17/76 Chamber No. 2

Project Frequency 4Fo Pattern Number 4

0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power

Transmitter Polarization: Vertical Horizontal Rotating Linear Circular

Test Sample Scale & Model

Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)

Remarks: —— V POL. DME ANTENNA PAIR 75° NOSE ELEVATION

---- H POL.

FIGURE B-4

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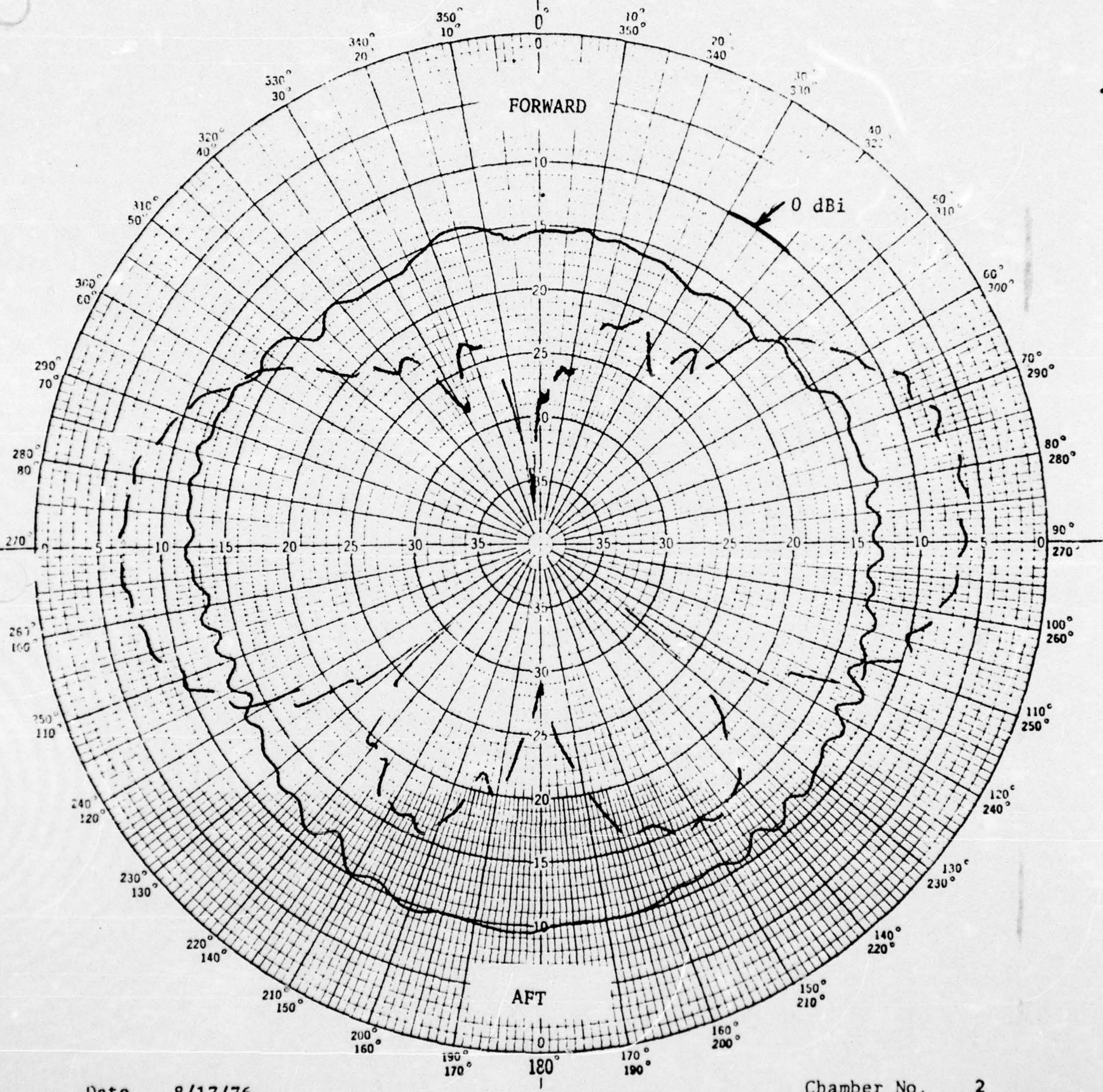
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/17/76 Chamber No. 2
Project Frequency 4Fo Pattern Number 5
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: —— V POL. DME ANTENNA PAIR 60° NOSE ELEVATION
---- H POL.

FIGURE B-5

IBM CORPORATION
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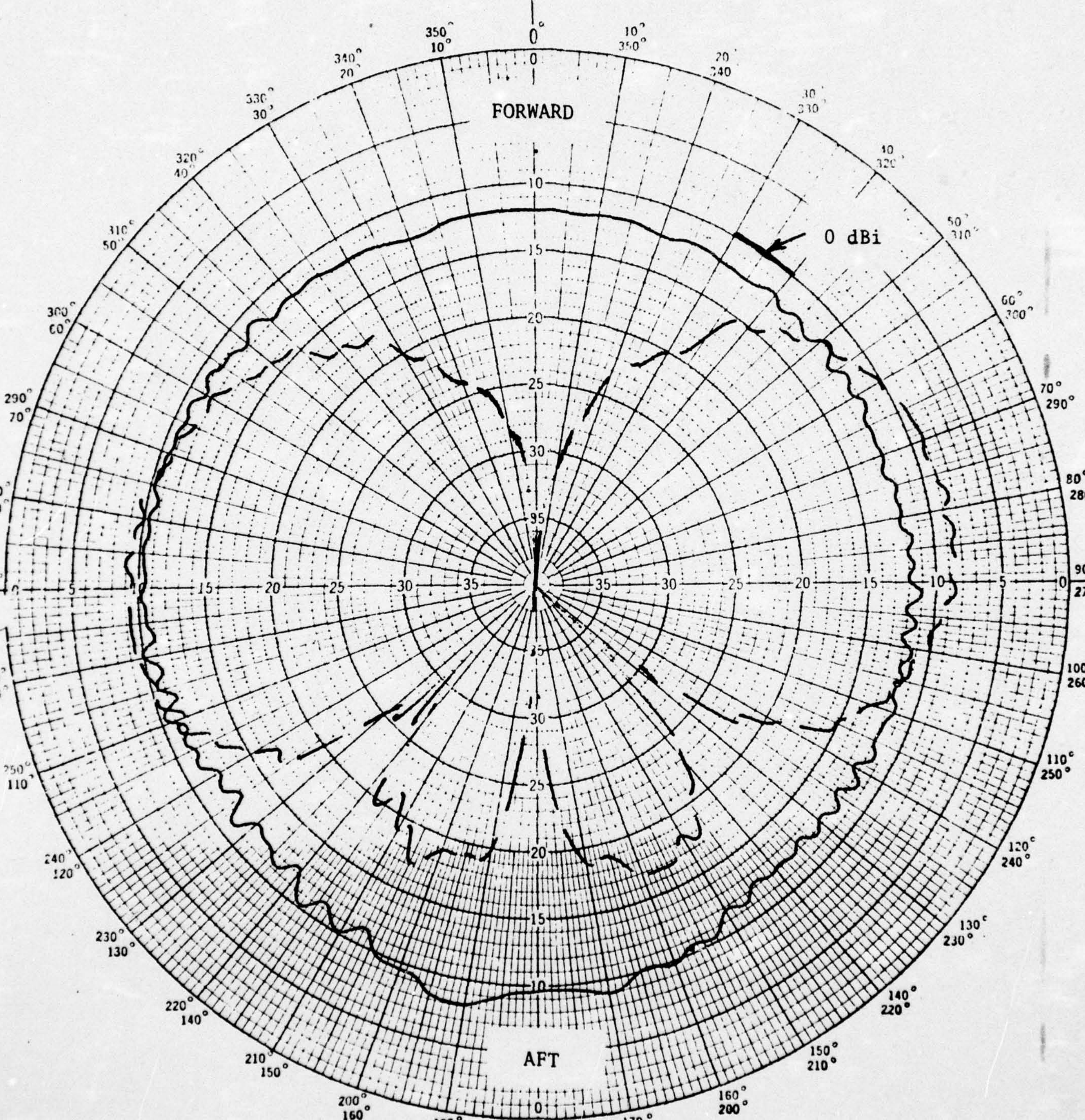
ANTENNA APPLICATIONS LABORATORY



Date 8/17/76 Chamber No. 2

Project ______ Frequency 4Fo Pattern Number 6

0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks:
—— V POL. DME ANTENNA PAIR 45° NOSE ELEVATION
----- H POL.

FIGURE B-6

IBM CORPORATION
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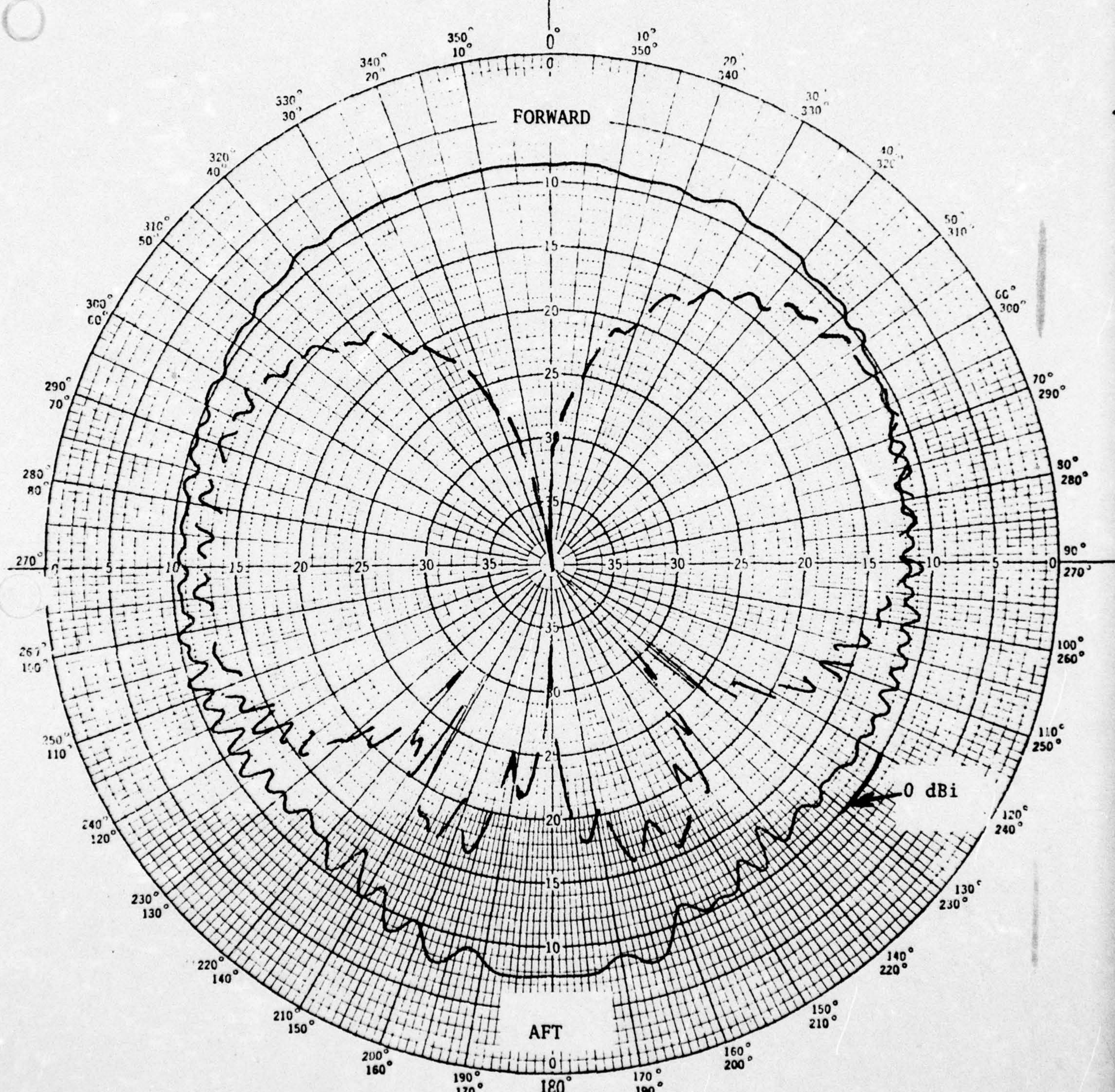
ANTENNA APPLICATIONS LABORATORY



Date 8/17/76 Chamber No. 2

Project ______ Frequency 4Fo Pattern Number 7

0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: ——— V POL. DME ANTENNA PAIR 30° NOSE ELEVATION

---- H POL.

FIGURE B-7

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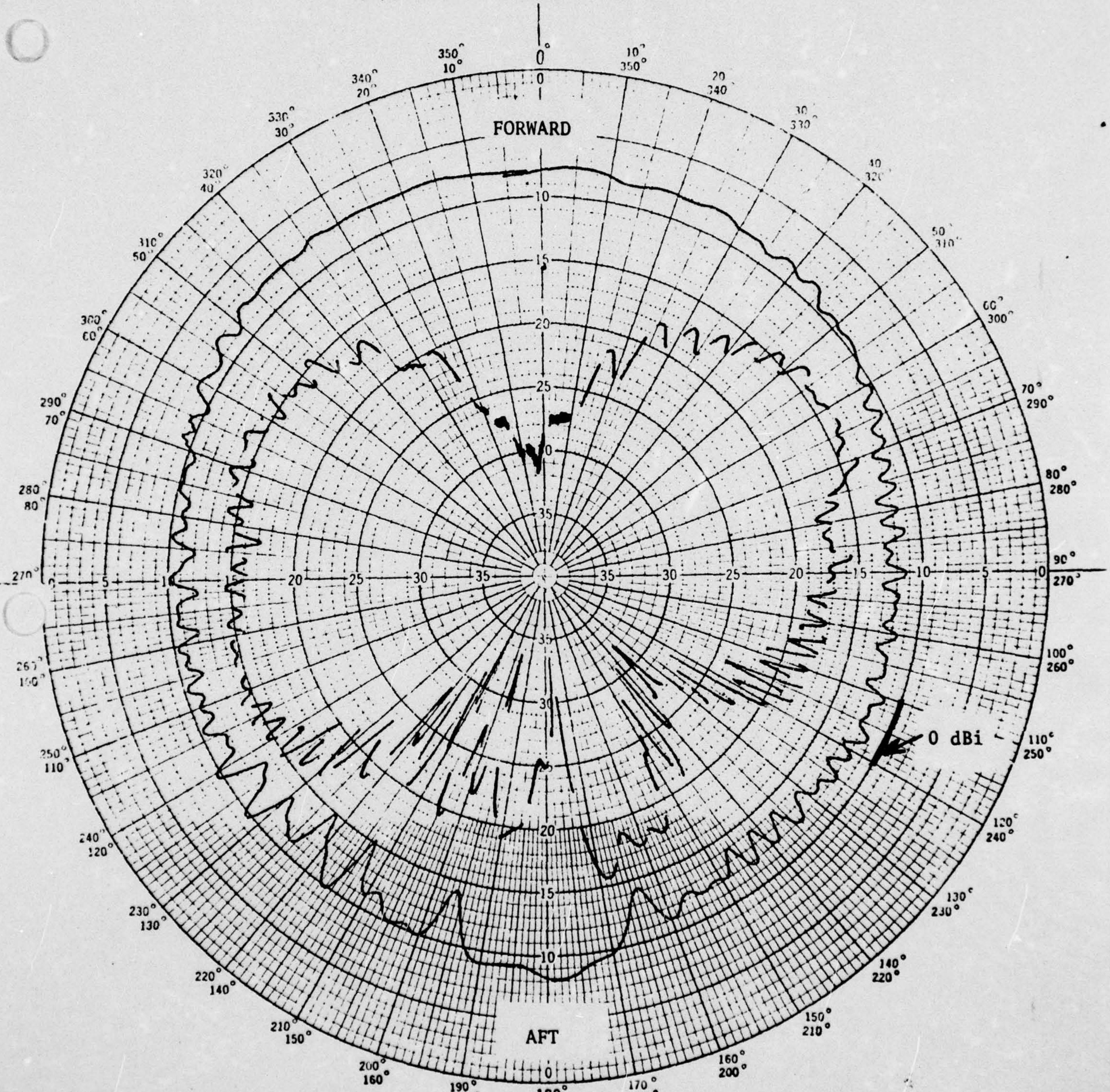
ANTENNA APPLICATIONS LABORATORY



Date 8/17/76 Chamber No. 2
Project Frequency 4Fo Pattern Number 8
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: ——— V POL. DME ANTENNA PAIR 15° NOSE ELEVATION
----- H POL.

FIGURE B-8

APPENDIX C

TELEMETRY ANTENNA PATTERNS

IBM CORPORATION
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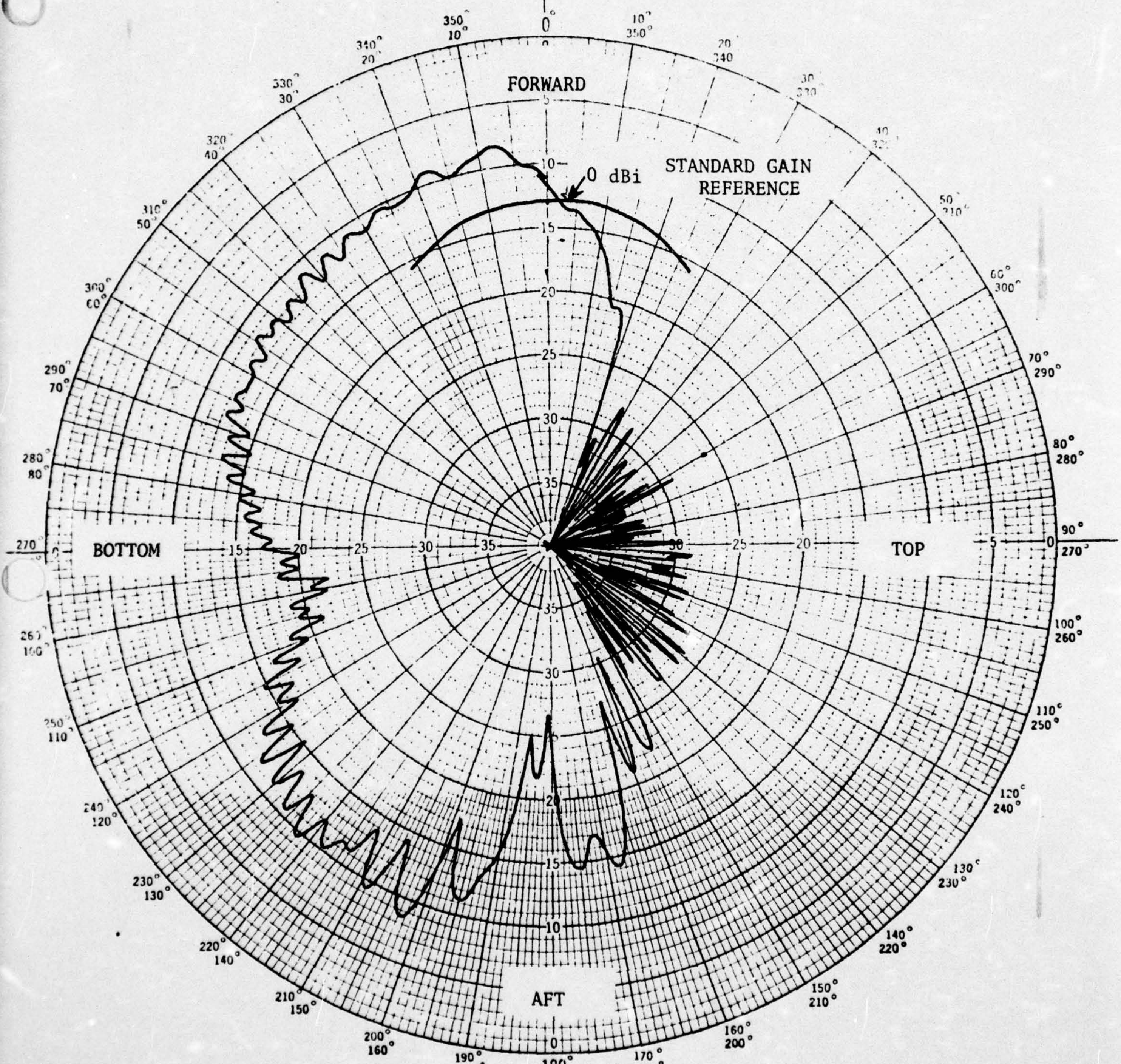
ANTENNA APPLICATIONS LABORATORY



Date 7/29/76 Chamber No. 2

Project ______ Frequency 8900 MC Pattern Number 1

0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

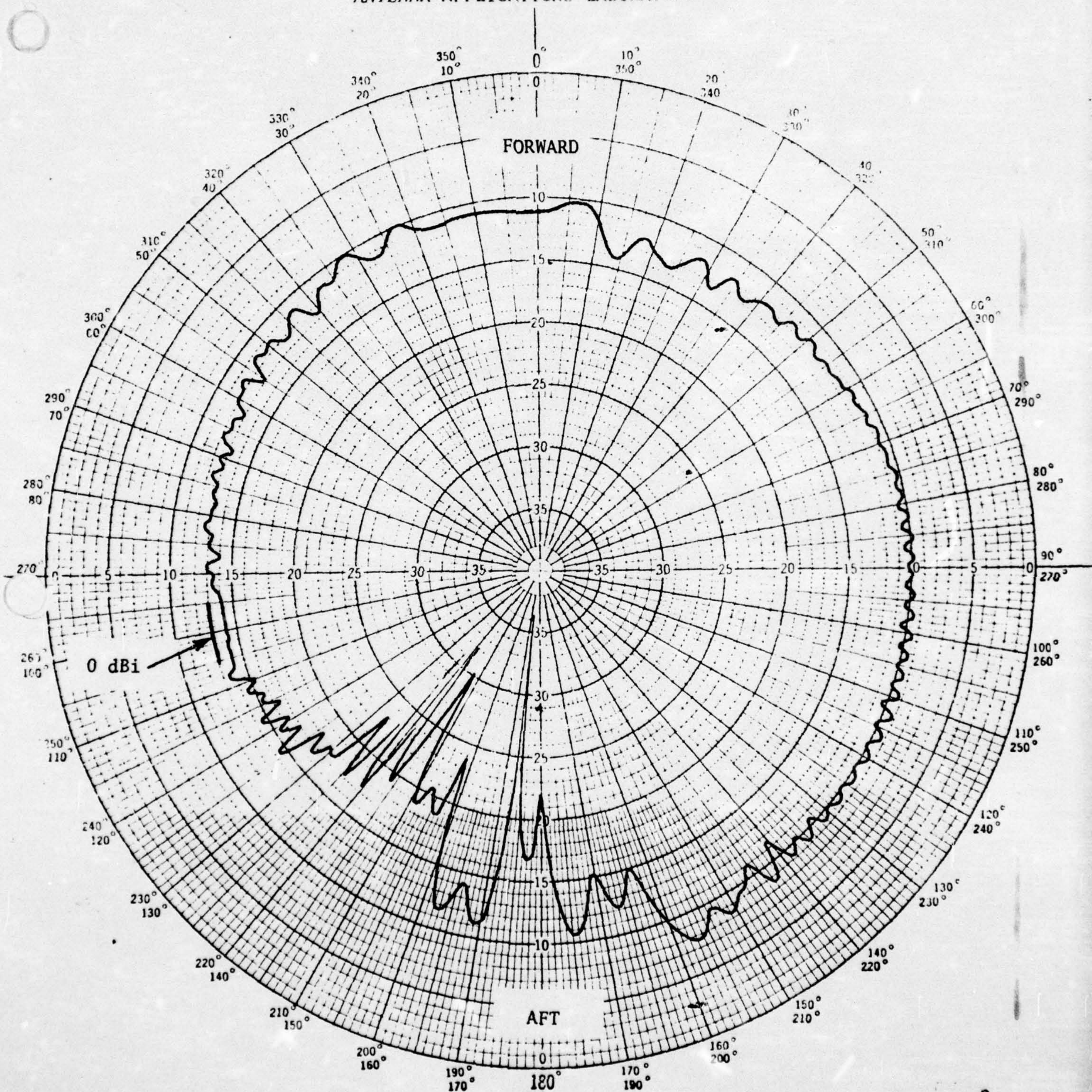
Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: CIRCULAR POL. PITCH PLANE

FIGURE C-1

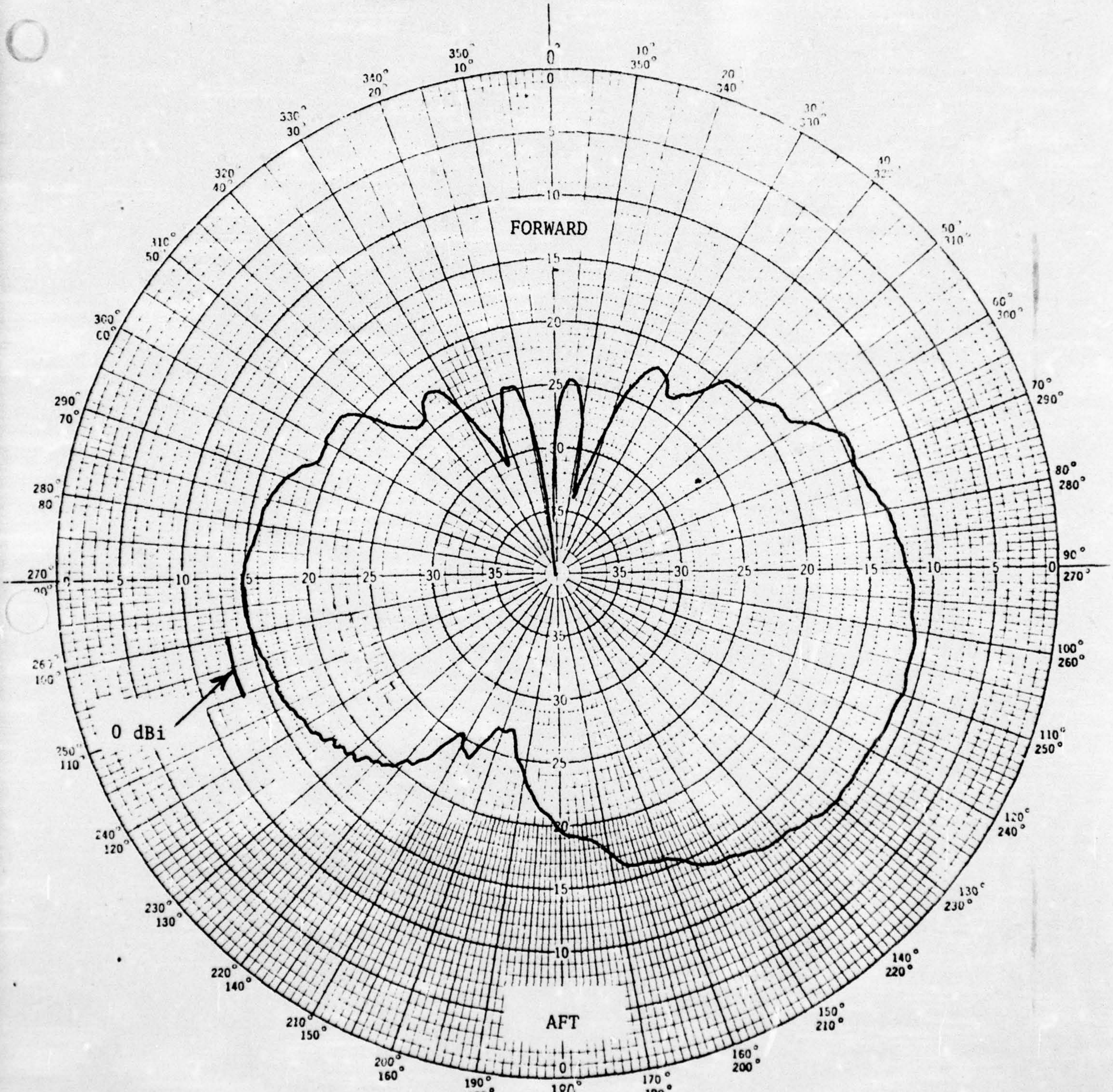
IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/29/76 Chamber No. 2
Project Frequency 8900 MC Pattern Number 2
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: CIRCULAR POL. YAW PLANE - 0° NOSE ELEVATION

FIGURE C-2

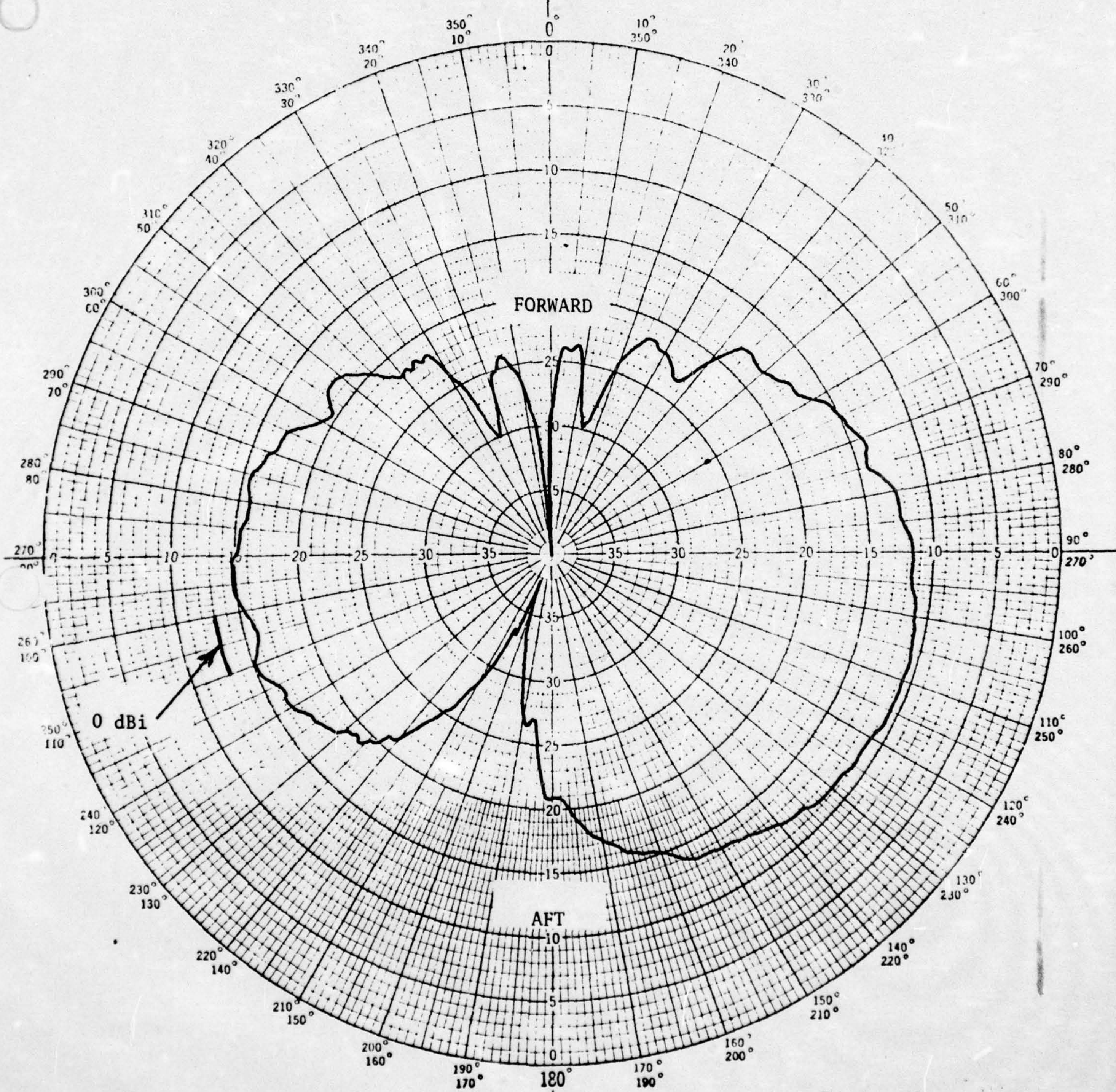
IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/29/76 Chamber No. 2
Project ________ Frequency 8900 MC Pattern Number 3
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ________ Scale & Model ________
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: CIRCULAR POL. ROLL PLANE - 90° NOSE DEPRESSION

FIGURE C-3

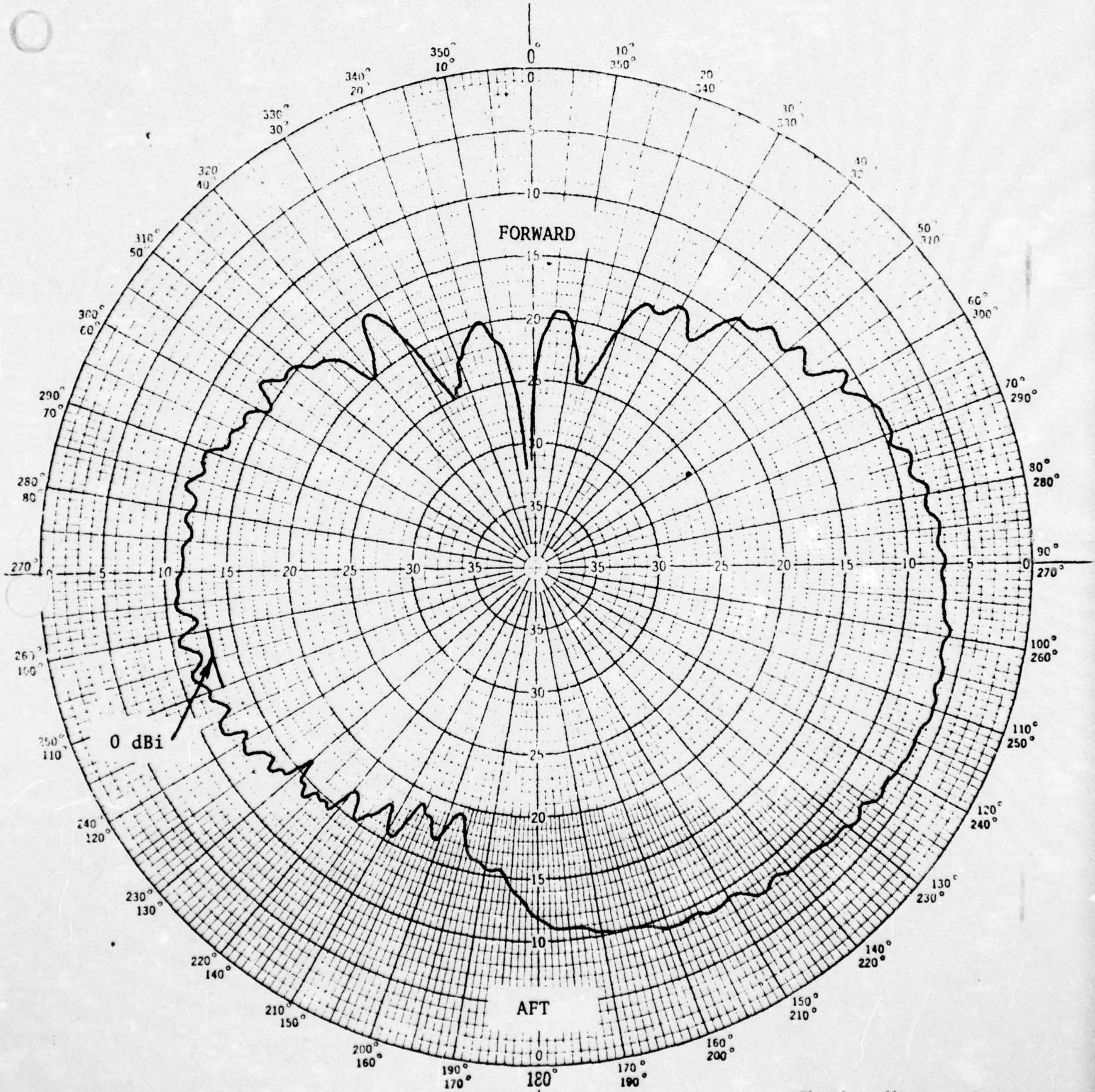
IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/29/76 Chamber No. 2
Project Frequency 8900 MC Pattern Number 4
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: CIRCULAR POL. 75° NOSE DEPRESSION

FIGURE C-4

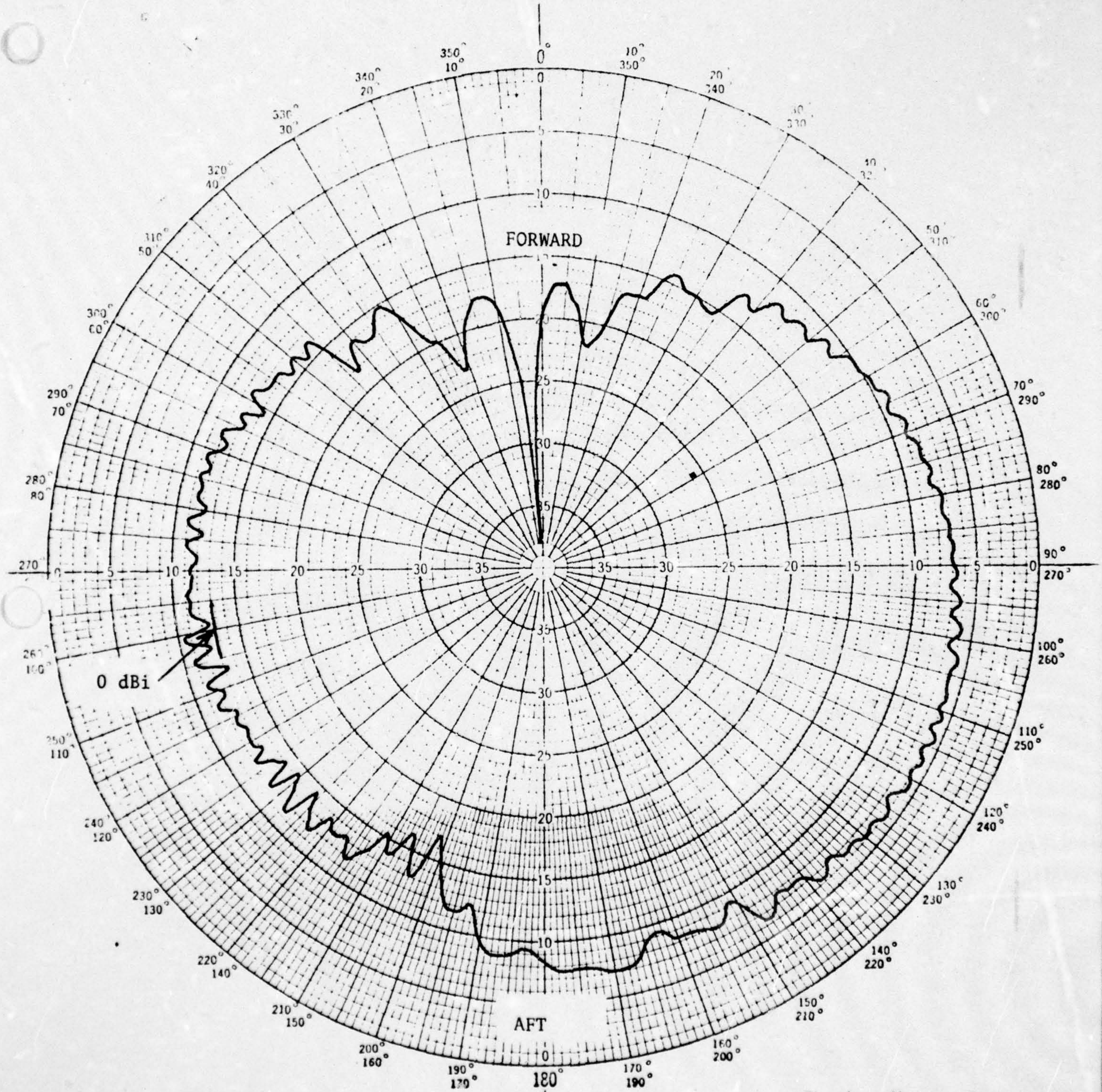
IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/29/76 Chamber No. 2
Project ___ Frequency 8900 MC Pattern Number 5
0 dB Gain Chart Level ___ dB, Curves Plotted in: Voltage ___ Linear (dB) ___ Power ___
Transmitter Polarization: Vertical ___ Horizontal ___ Rotating Linear ___ Circular ___
Test Sample ___ Scale & Model ___
Test Sample Polarization: Vertical ___ Horizontal ___ Circular (L-H) ___ (R-H) ___
Remarks: CIRCULAR POL. 60° NOSE DEPRESSION

FIGURE C-5

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/29/76 Chamber No. 2

Project ______ Frequency 8900 MC Pattern Number 6

0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: CIRCULAR POL. 45° NOSE DEPRESSION

FIGURE C-6

AD-A032 155 IBM FEDERAL SYSTEMS DIV OWEGO N Y F/G 16/4.1

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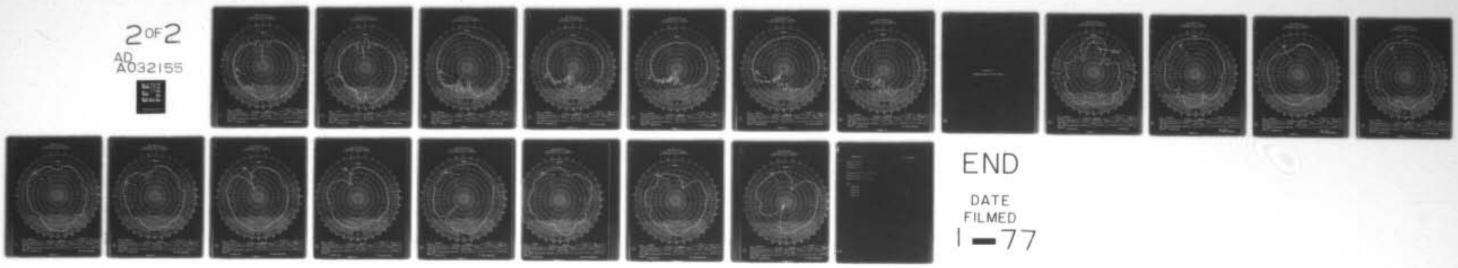

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DATE FILMED

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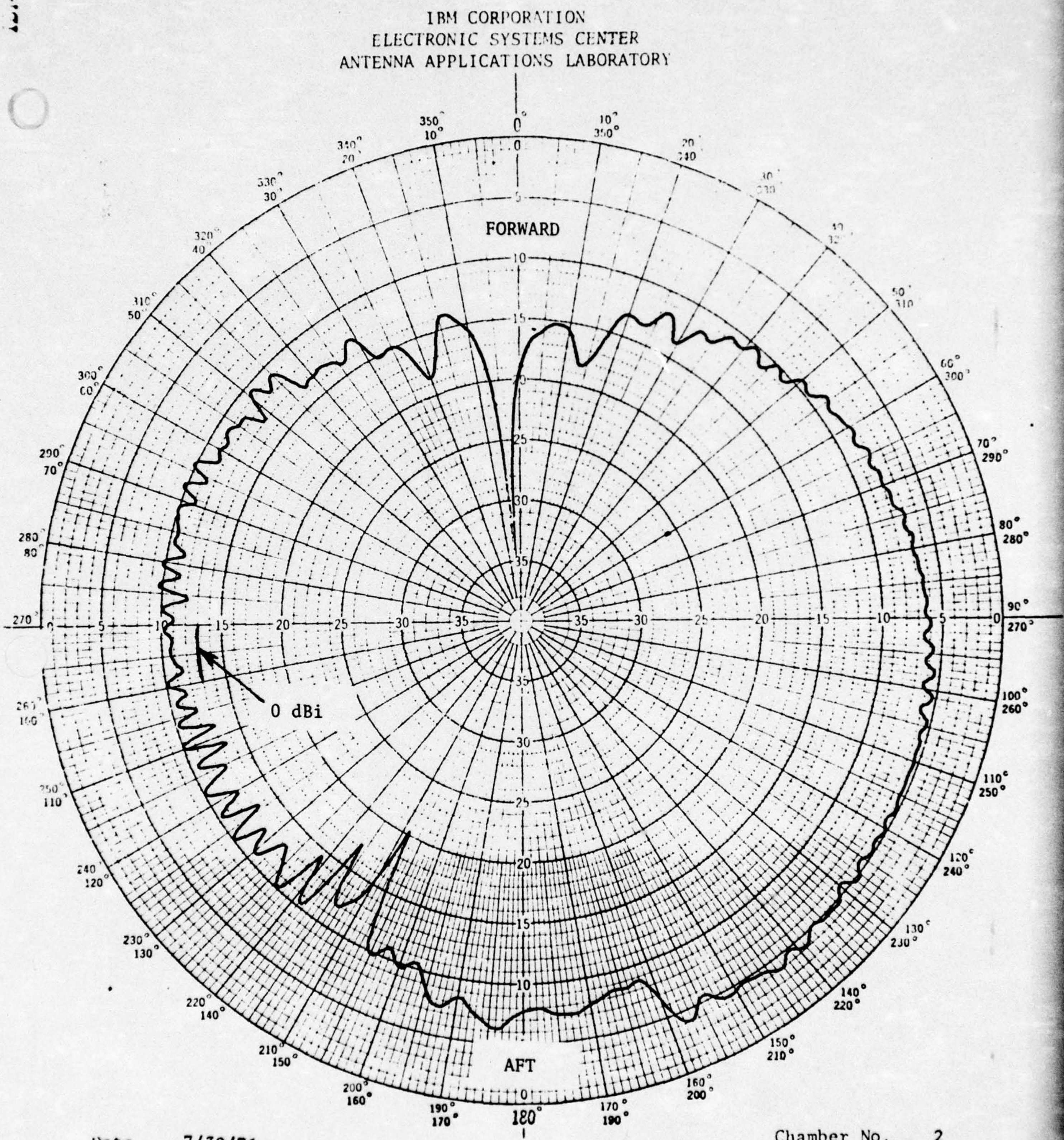


Date 7/30/76 Chamber No. 2

Project Frequency 8900 MC Pattern Number 7

0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power

Transmitter Polarization: Vertical Horizontal Rotating Linear Circular

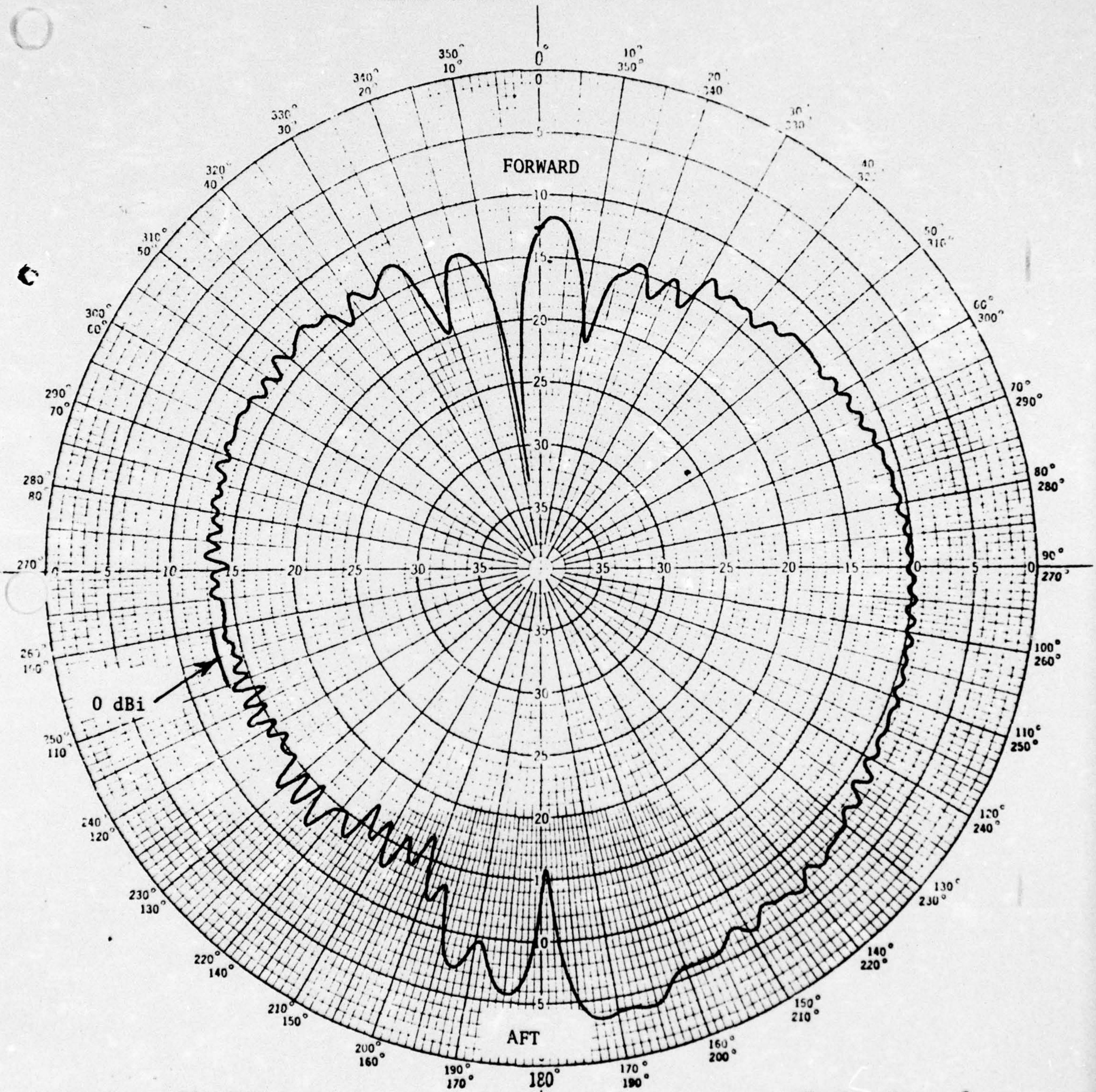
Test Sample Scale & Model

Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)

Remarks: CIRCULAR POL. 30° NOSE DEPRESSION

FIGURE C-7

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/30/76 Chamber No. 2

Project ______ Frequency 8900 MC Pattern Number 8

0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: CIRCULAR POL. 15° NOSE DEPRESSION

FIGURE C-8

IBM CORPORATION
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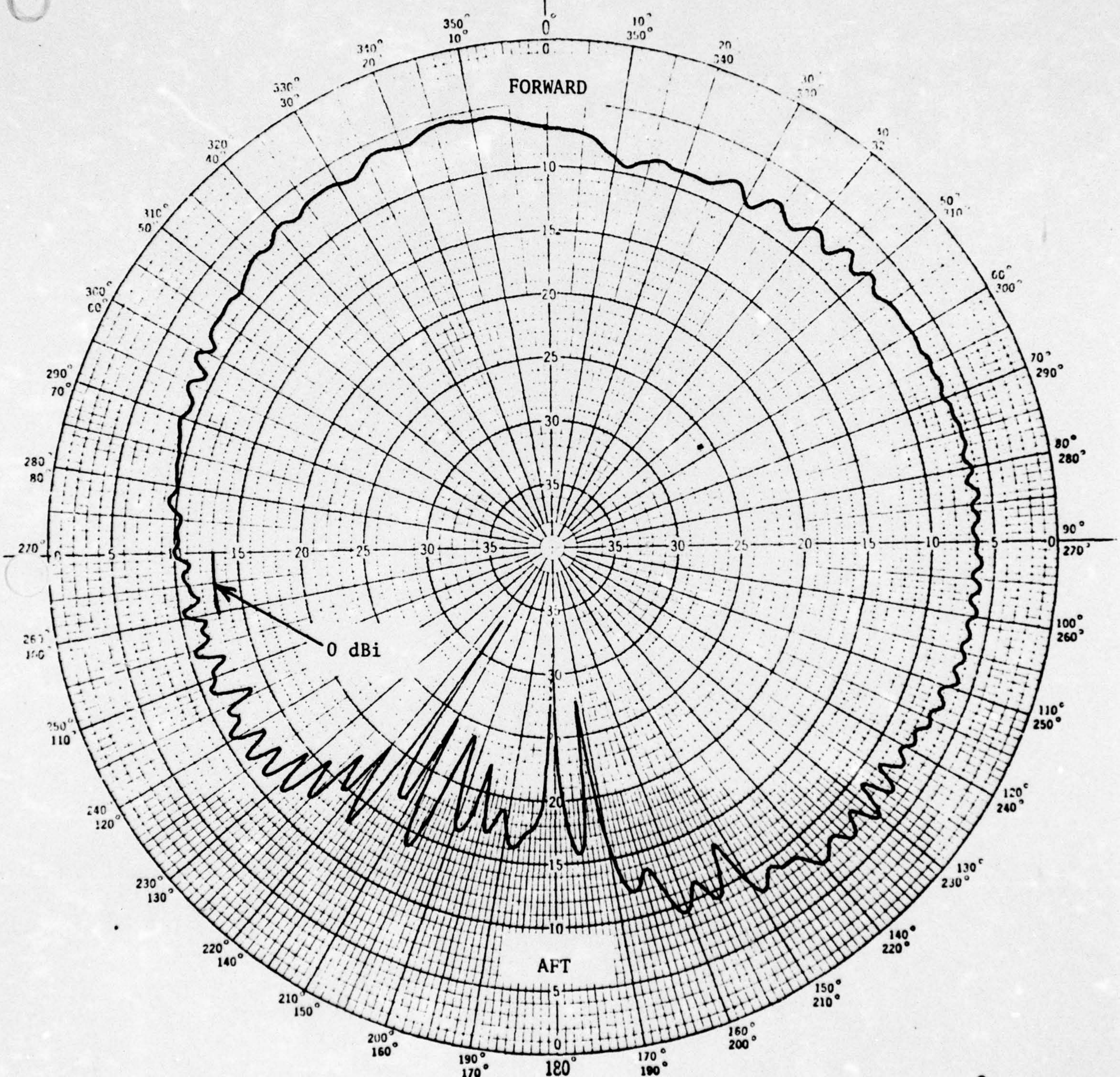
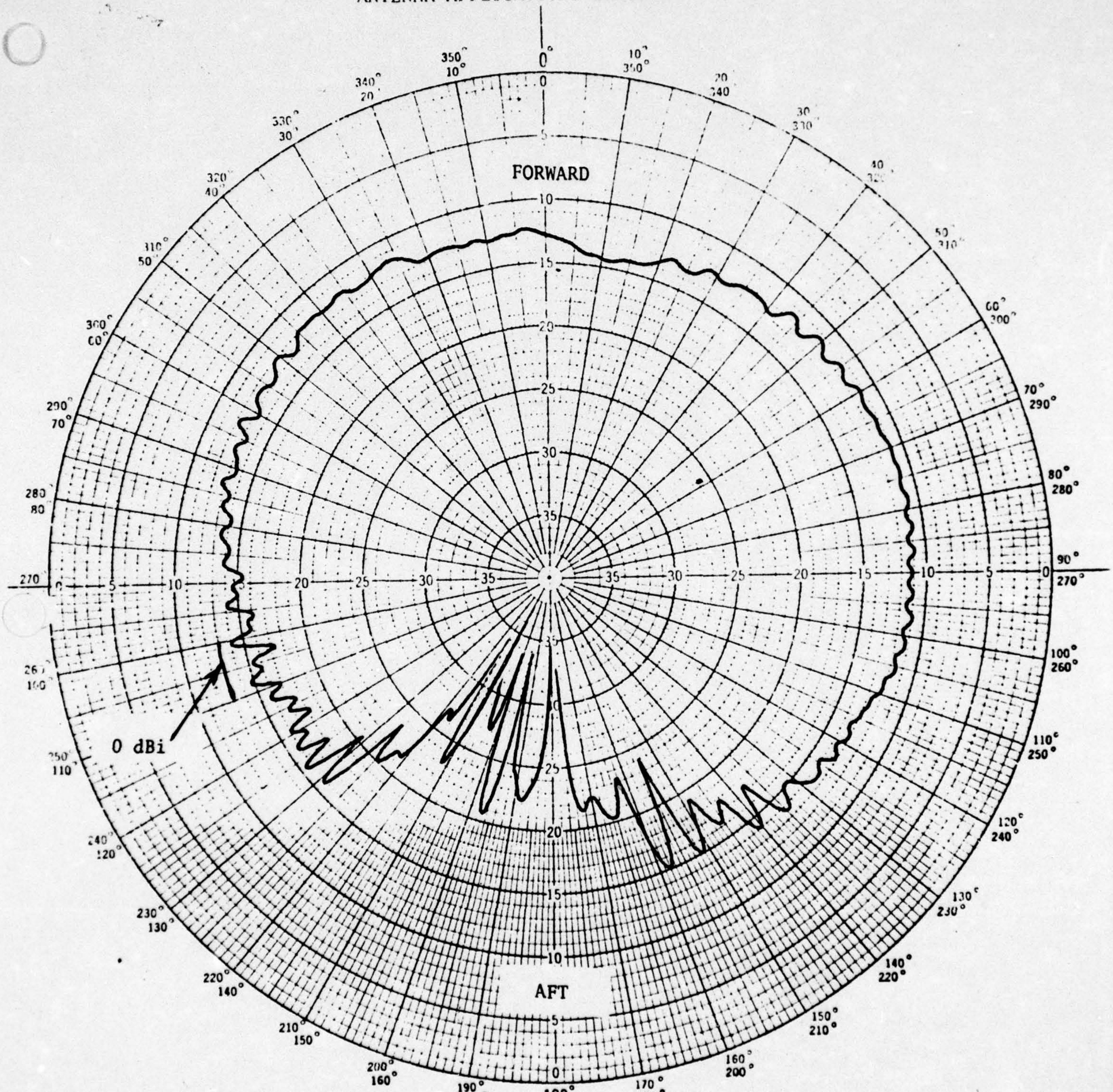
ANTENNA APPLICATIONS LABORATORY



Date 7/30/76 Chamber No. 2
Project Frequency 8900 MC Pattern Number 9
0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power
Transmitter Polarization: Vertical Horizontal Rotating Linear Circular
Test Sample Scale & Model
Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)
Remarks: CIRCULAR POL. 15° NOSE ELEVATION

FIGURE C-9

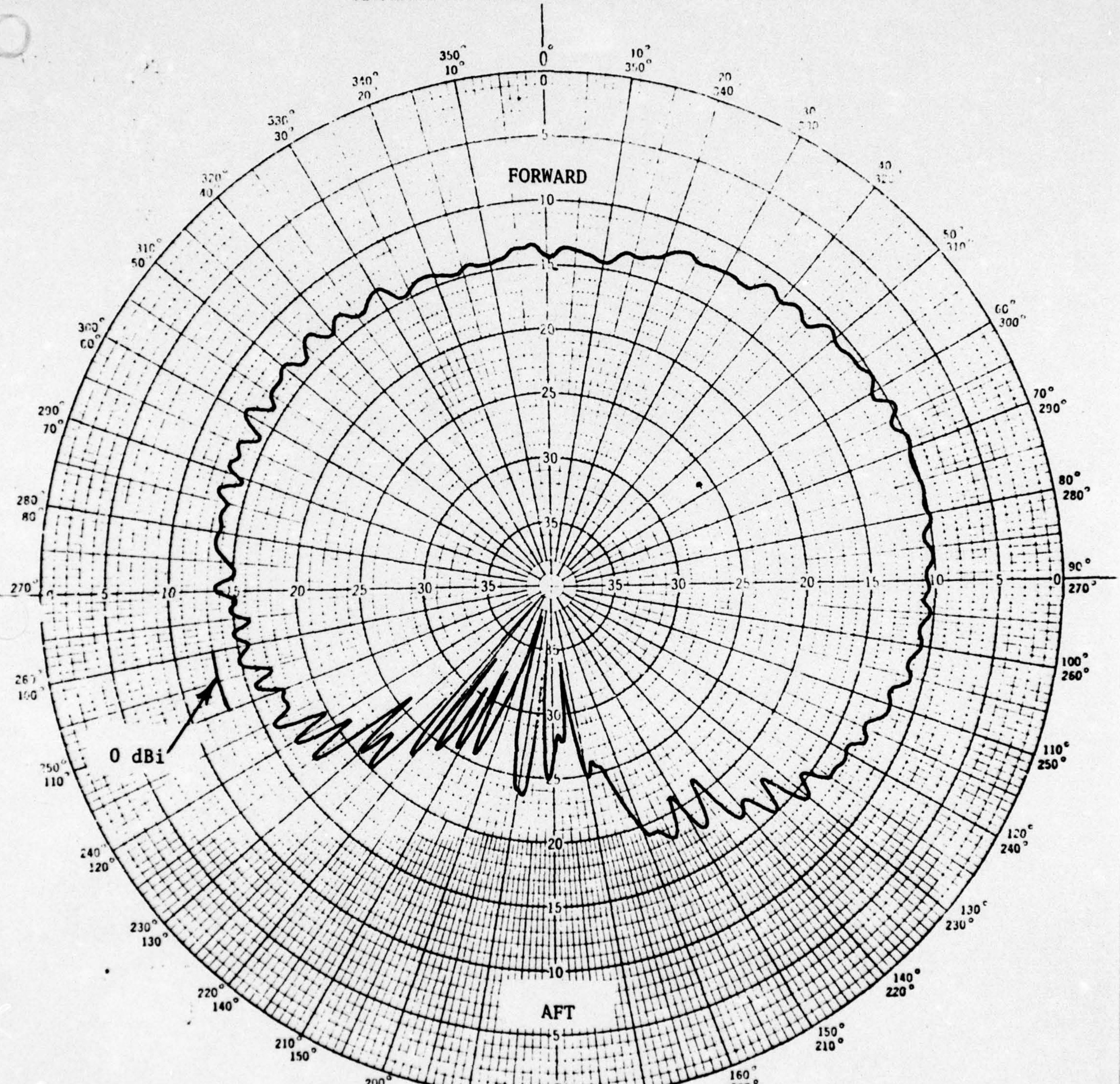
IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/30/76 Chamber No. 2
Project Frequency 8900 MC Pattern Number 10
0 dB Gain Chart Level dB,Curves Plotted in: Voltage Linear (dB) Power
Transmitter Polarization: Vertical Horizontal Rotating Linear Circular
Test Sample Scale & Model
Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)
Remarks: CIRCULAR POL. 30° NOSE ELEVATION

FIGURE C-10

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/30/76

Chamber No. 2

Project ______ Frequency 8900 MC Pattern Number 11

0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ___ Linear (dB) ___ Power ___

Transmitter Polarization: Vertical ___ Horizontal ___ Rotating Linear ___ Circular ___

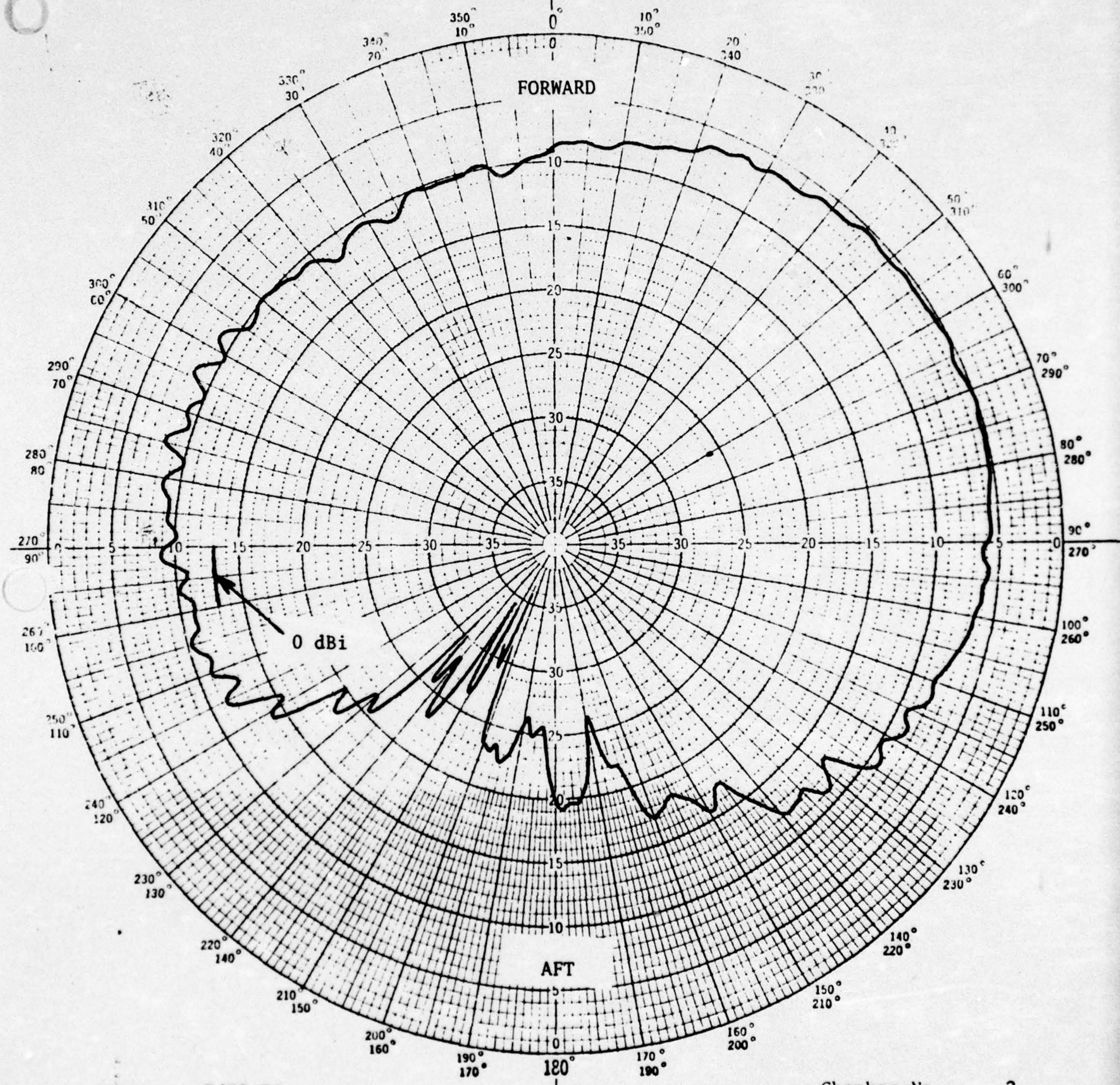
Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ___ Horizontal ___ Circular (L-H) ___ (R-H) ___

Remarks: CIRCULAR POL. 45° NOSE ELEVATION

FIGURE C-11

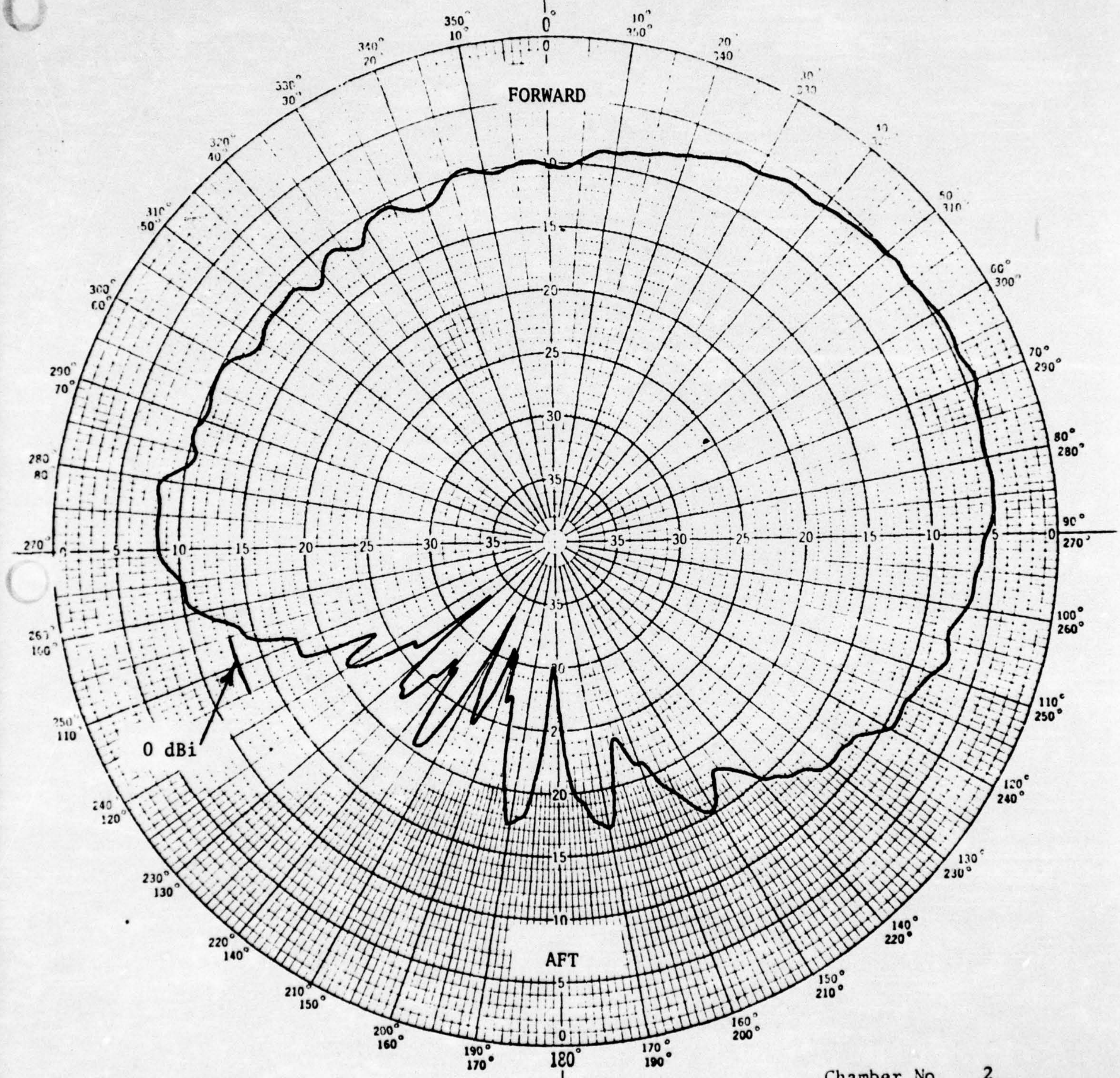
IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/30 76 Chamber No. 2
Project Frequency 8900 MC Pattern Number 12
0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power
Transmitter Polarization: Vertical Horizontal Rotating Linear Circular
Test Sample Scale & Model
Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)
Remarks: CIRCULAR POL. 60° NOSE ELEVATION

FIGURE C-12

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 7/30/76 Chamber No. 2
Project Frequency 8900 MC Pattern Number 13
0 dB Gain Chart Level dB, Curves Plotted in: Voltage Linear (dB) Power
Transmitter Polarization: Vertical Horizontal Rotating Linear Circular
Test Sample Scale & Model
Test Sample Polarization: Vertical Horizontal Circular (L-H) (R-H)
Remarks: CIRCULAR POL. 75° NOSE ELEVATION

FIGURE C-13

APPENDIX D

COMMAND DESTRUCT ANTENNA PATTERNS

IBM CORPORATION
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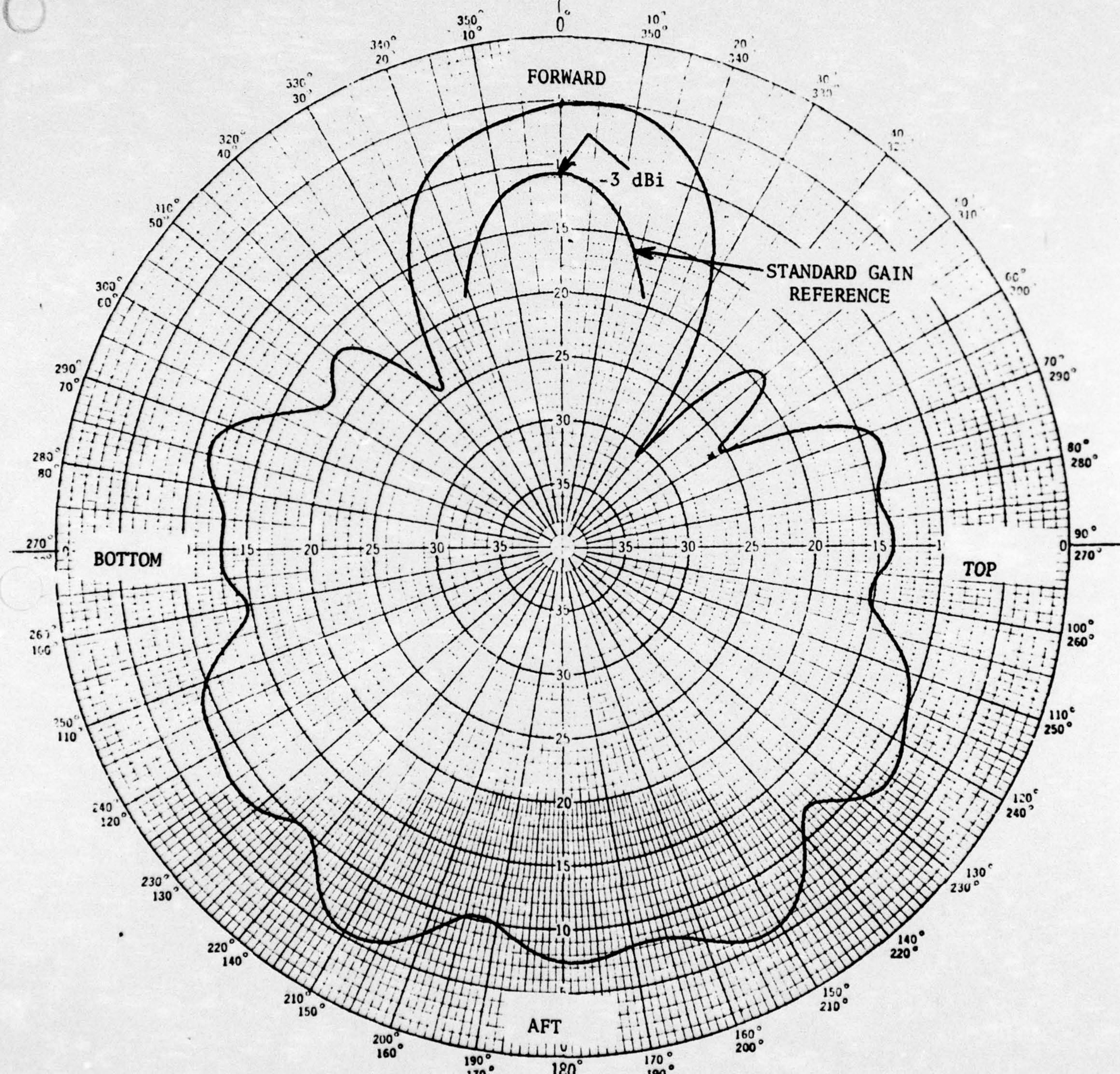
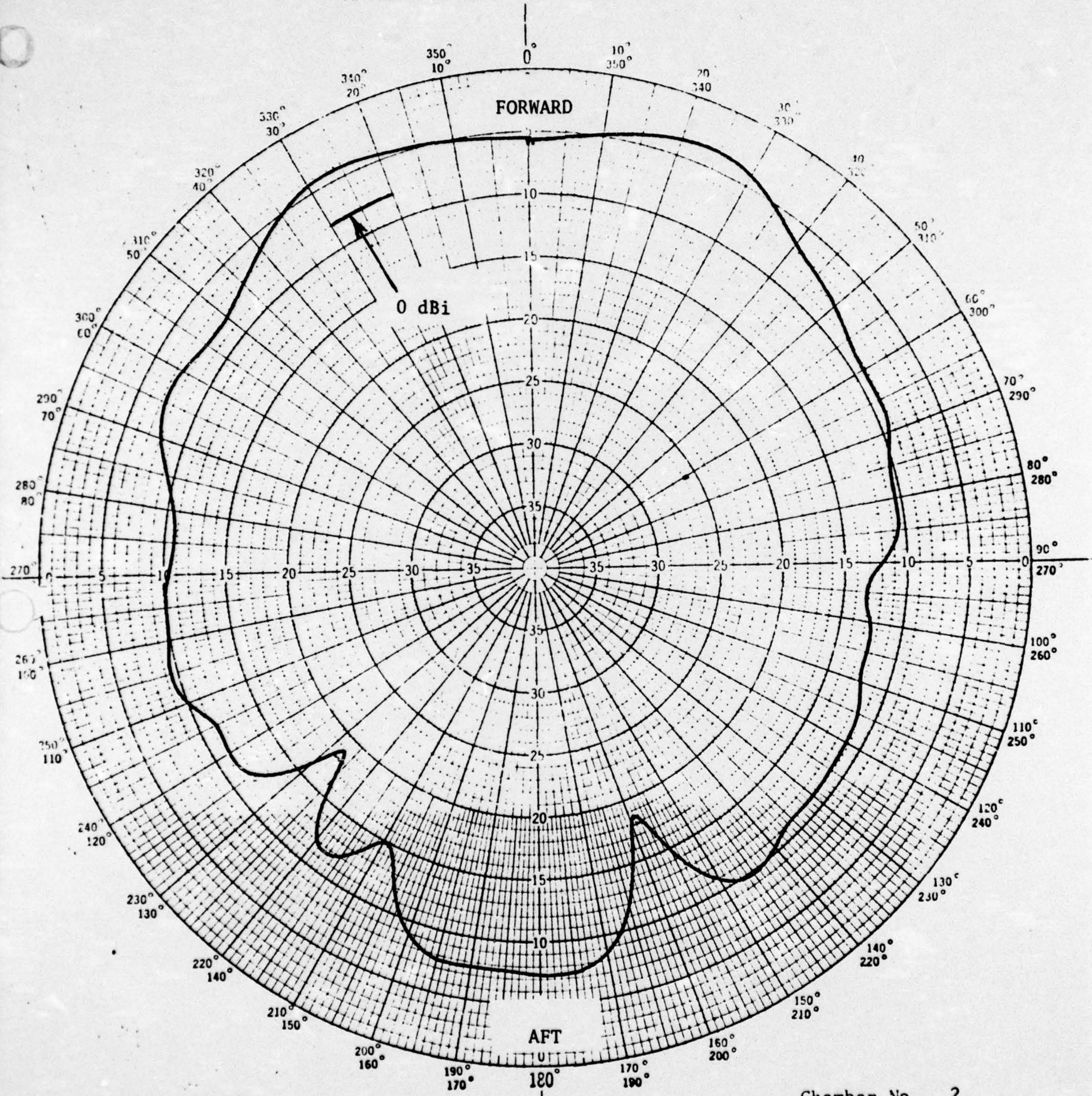
ANTENNA APPLICATIONS LABORATORY



Date 8/4/76 Chamber No. 2
Project Frequency 1636 MC Pattern Number 5
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks:
CIRCULAR POL. PITCH PLANE

FIGURE D-1

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/12/76

Project

Frequency 1636 MC

Chamber No. 2

Pattern Number 4

0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ____ Scale & Model ____

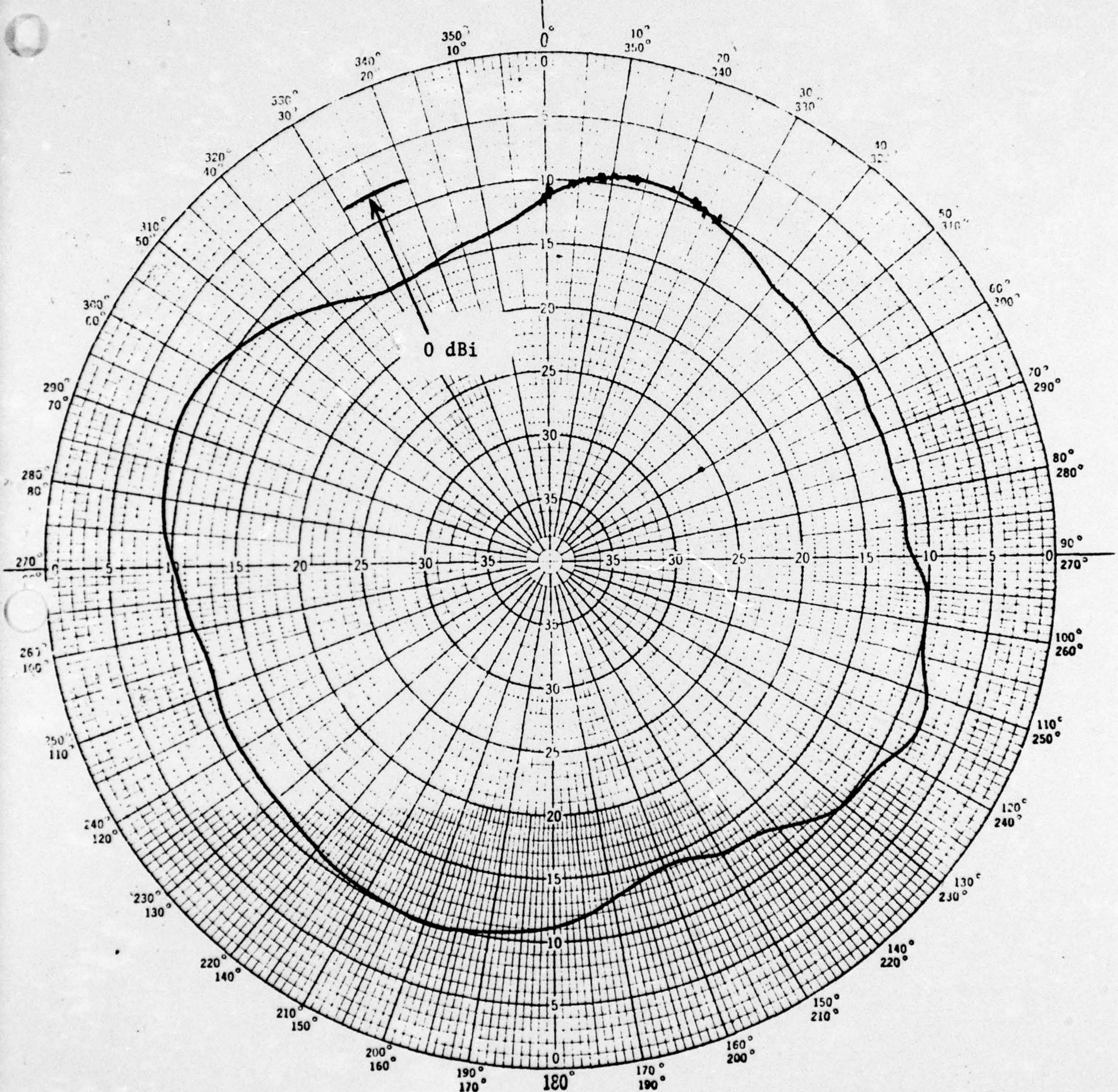
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: CIRCULAR POL.

YAW PLANE
0° NOSE ELEVATION

FIGURE D-2

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/12/76 Chamber No. 2

Project Frequency 1636 MC Pattern Number 3

0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ____ Scale & Model ____

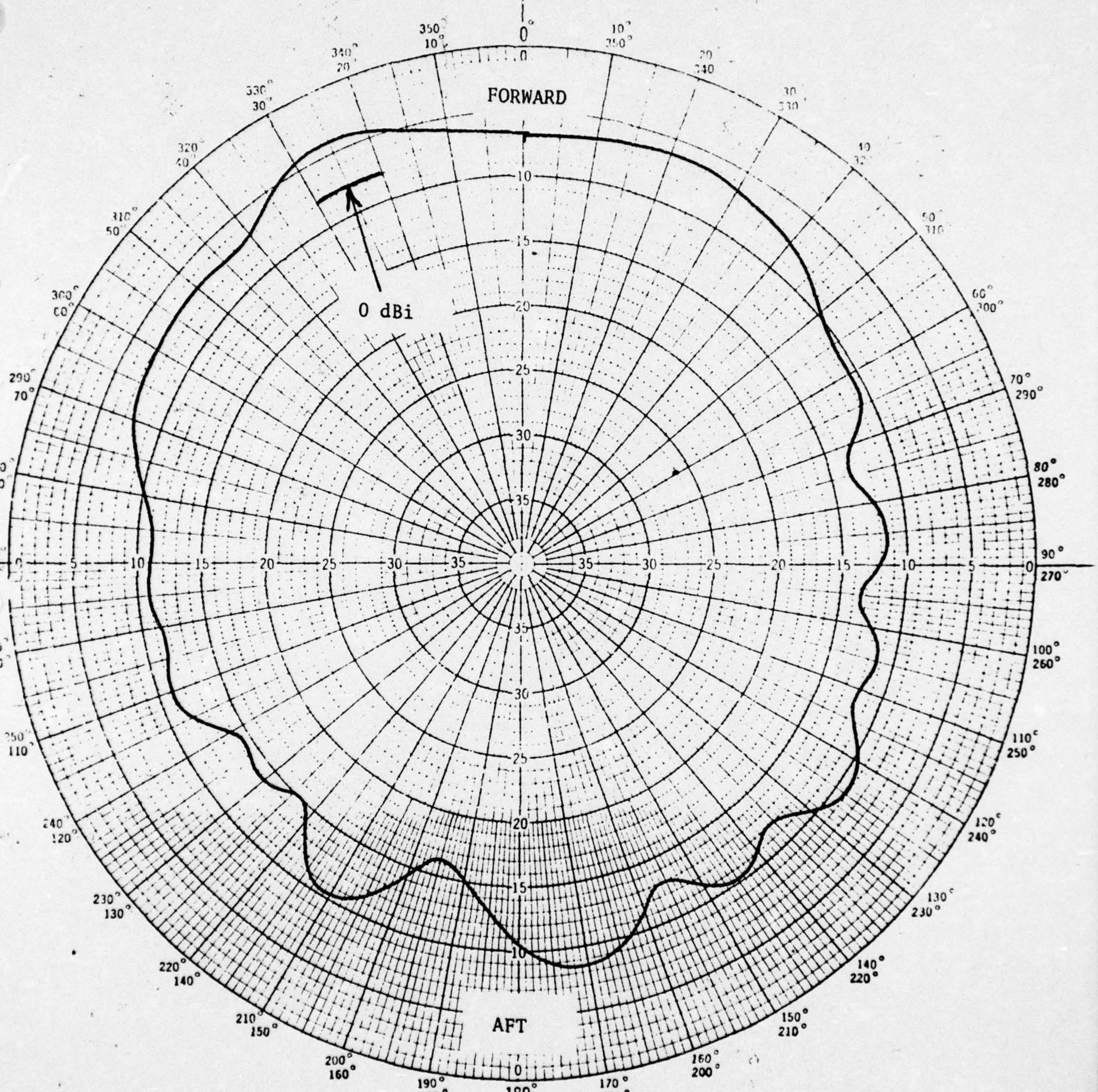
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: CIRCULAR POL.

ROLL PLANE
90° NOSE ELEVATION

FIGURE D-3

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/3/76 Chamber No. 2

Project ____ Frequency 1636 MC Pattern Number 5

0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ____ Scale & Model ____

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks: CIRCULAR POL. 15° NOSE ELEVATION

FIGURE D-4

IBM CORPORATION
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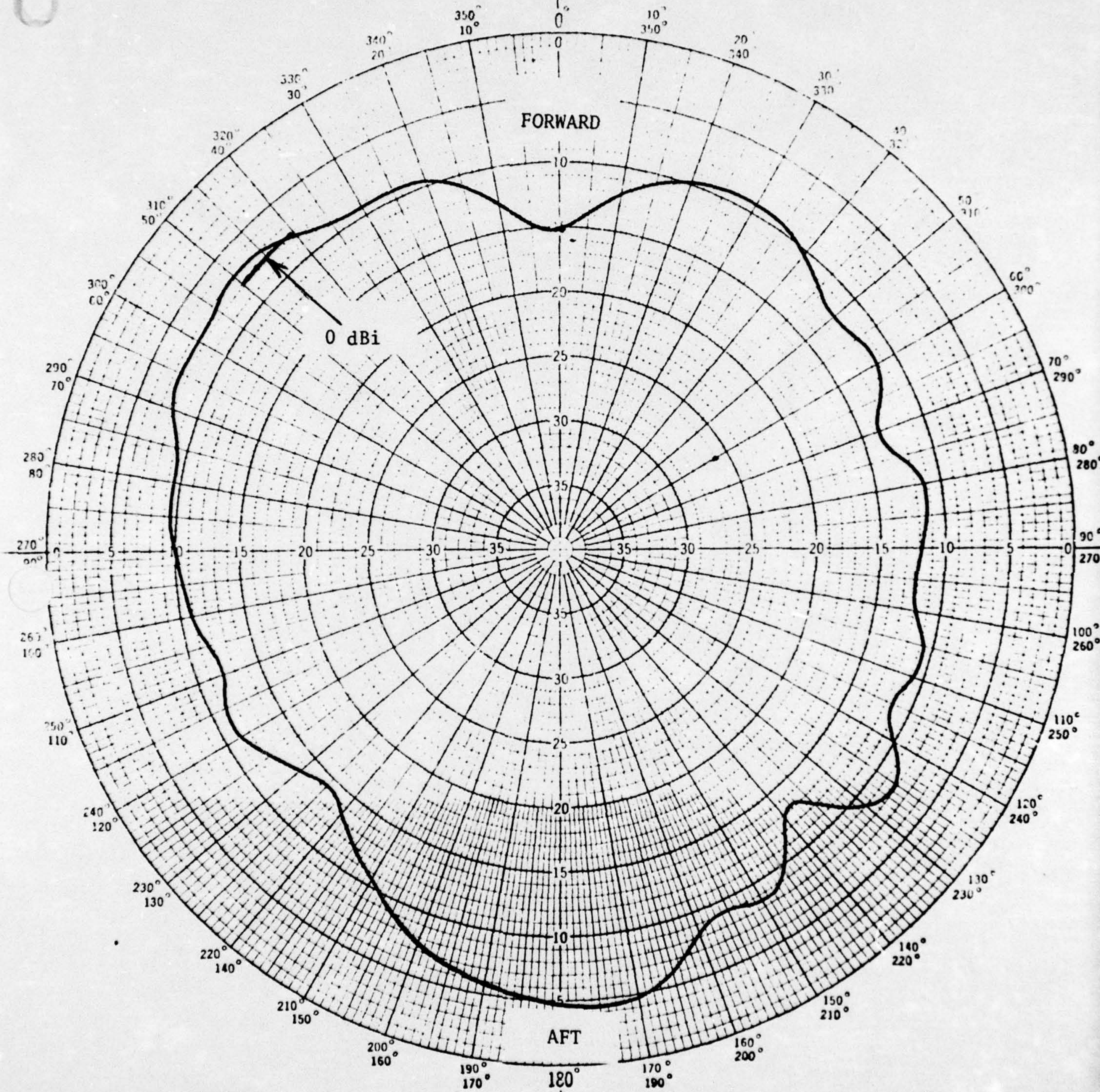
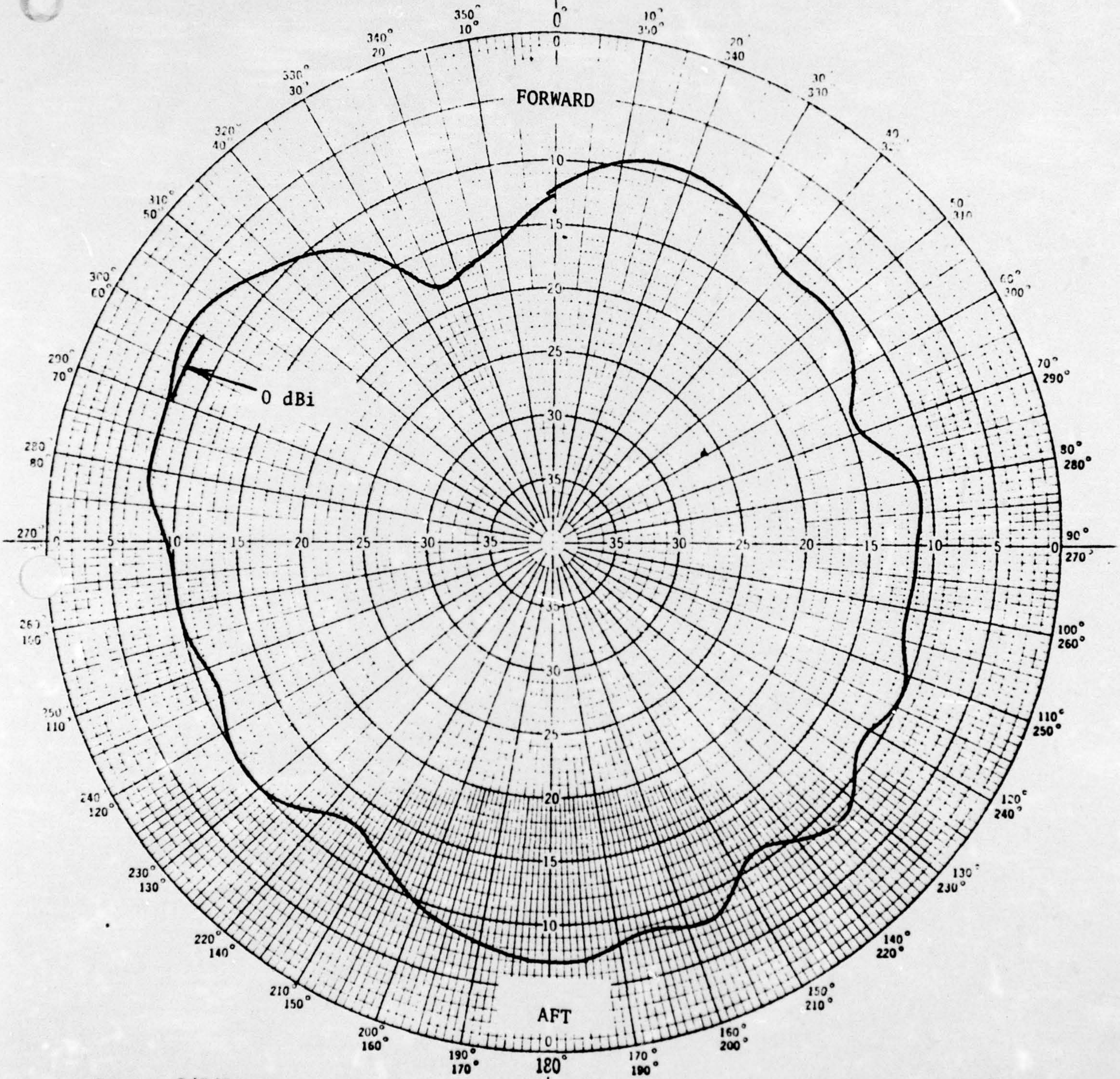
ANTENNA APPLICATIONS LABORATORY



Date 8/3/76 Chamber No. 2
Project Frequency 1636 MC Pattern Number 6
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: CIRCULAR POL. 30° NOSE ELEVATION

FIGURE D-5

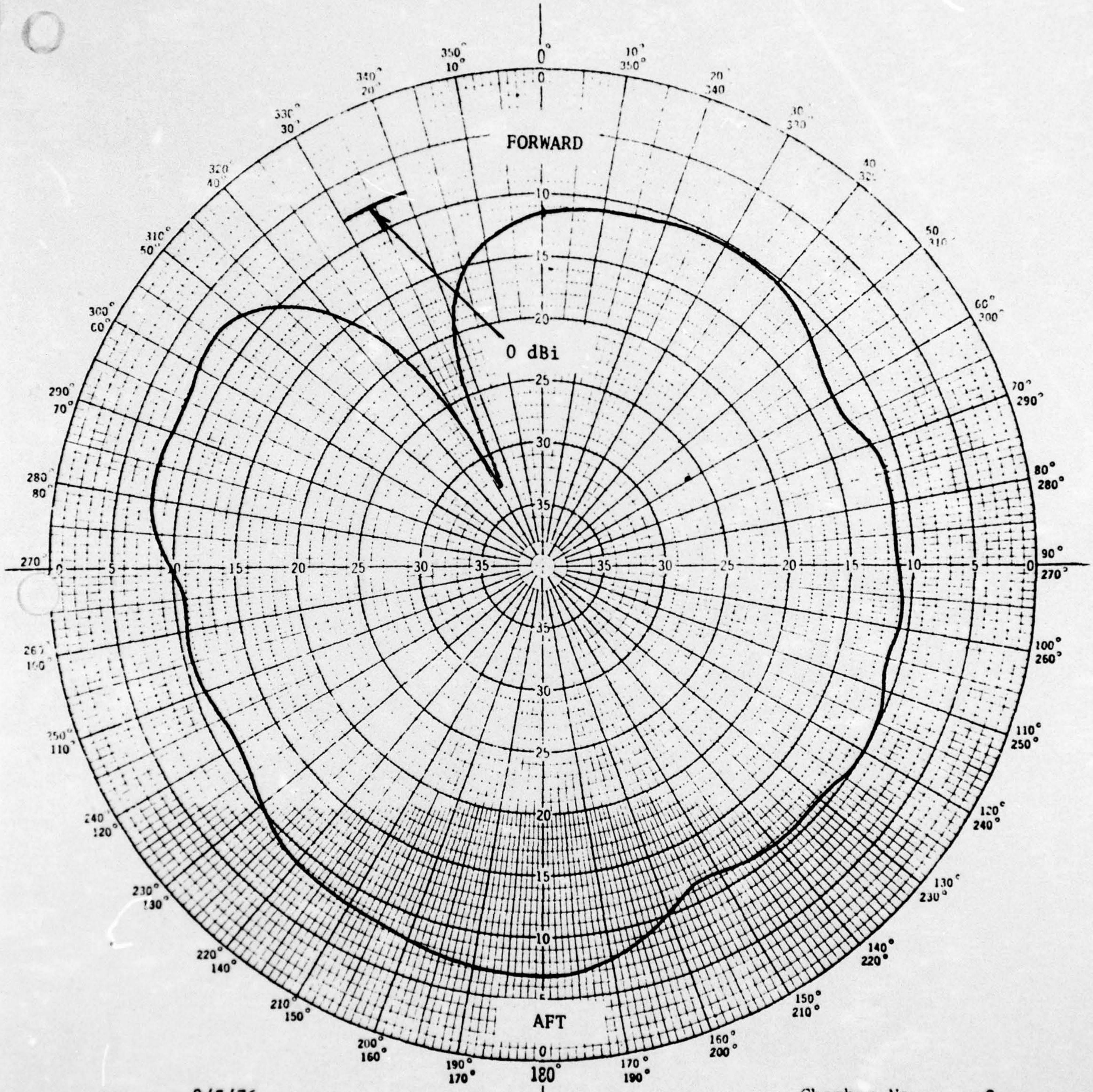
IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/3/76 Chamber No. 2
Project ______ Frequency 1636 MC Pattern Number 7
0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ______ Scale & Model ______
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: CIRCULAR POL. 45° NOSE ELEVATION

FIGURE D-6

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/3/76 Chamber No. 2

Project ____ Frequency 1636 MC Pattern Number 8

0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ____ Scale & Model ____

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks:

CIRCULAR POL. 60° NOSE ELEVATION

FIGURE D-7

IBM CORPORATION
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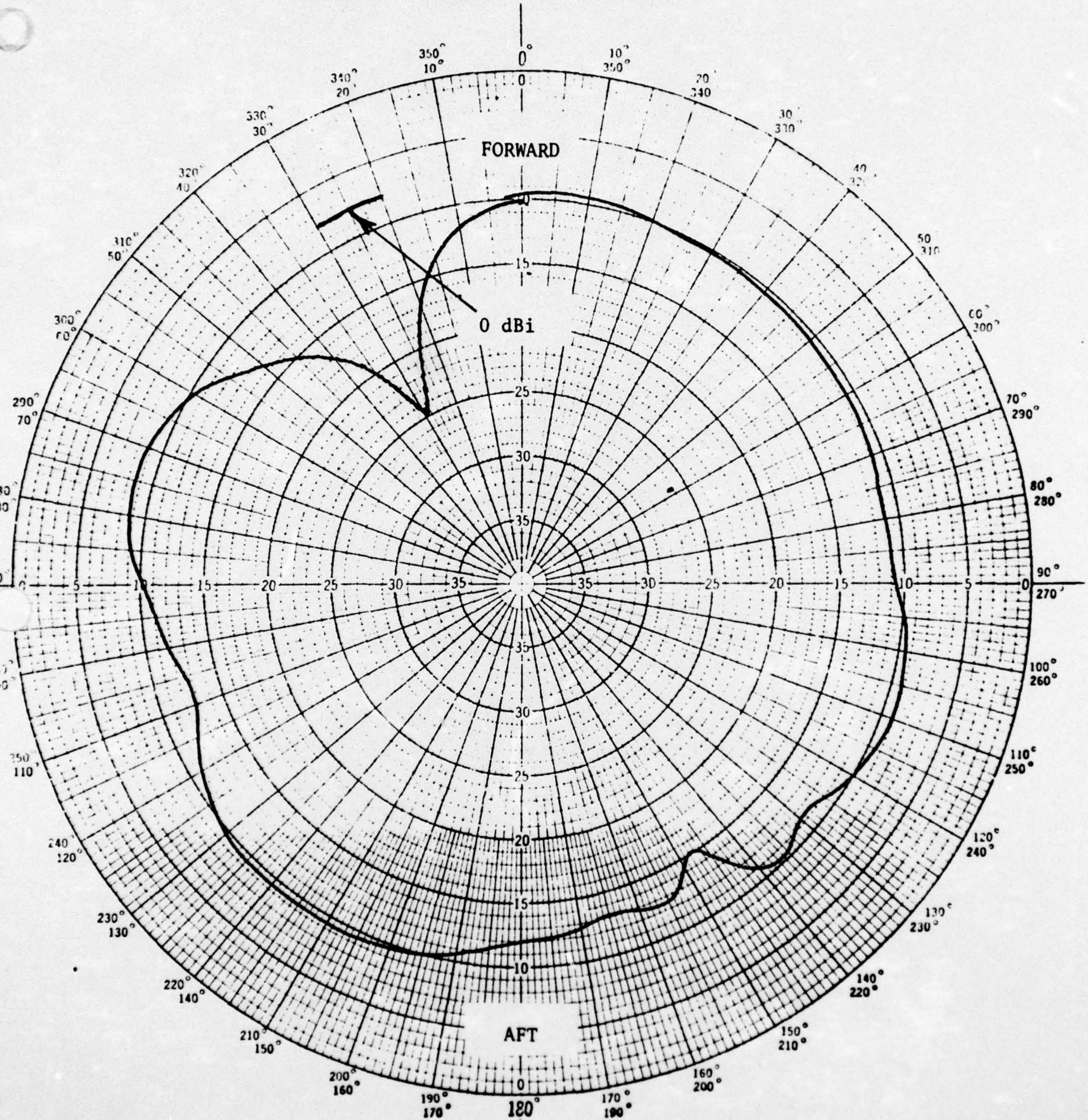

Date 8/3/76 Chamber No. 2
Project ____ Frequency 1636 MC Pattern Number 9
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks:

CIRCULAR POL. 75° NOSE ELEVATION

FIGURE D-8

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
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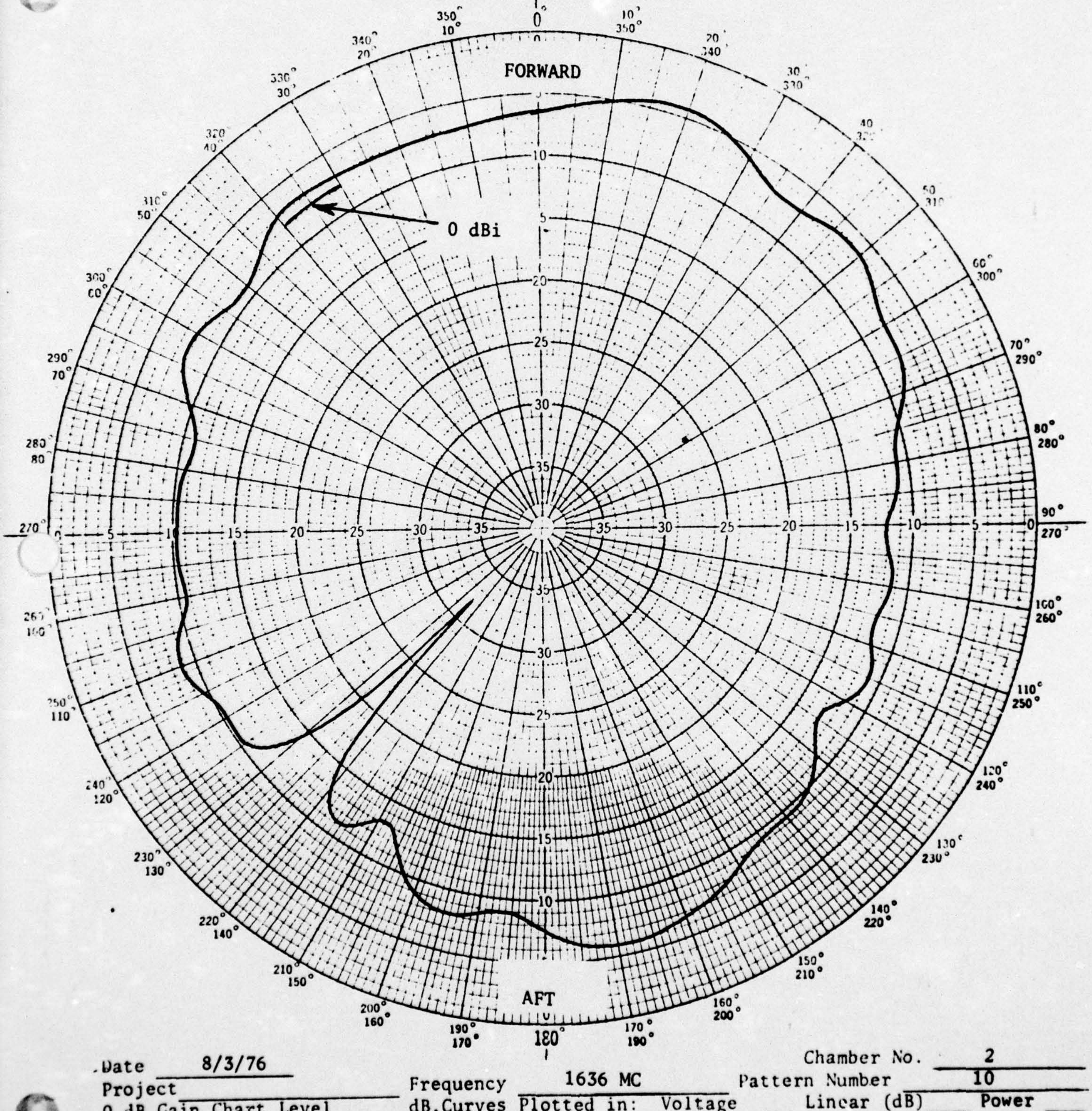
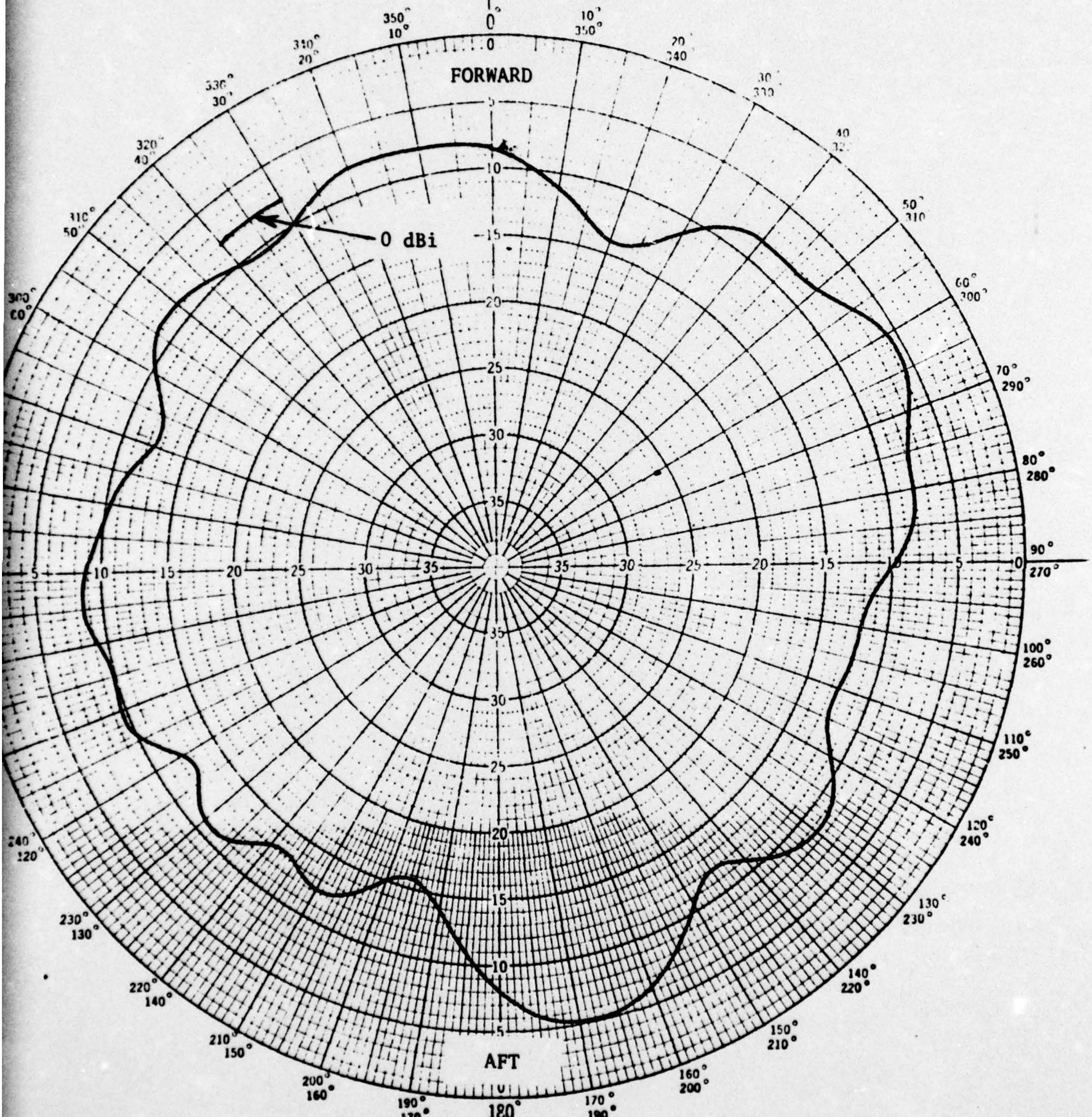


Date 8/3/76
Chamber No. 2
Project
Frequency 1636 MC
Pattern Number 10
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: CIRCULAR POL. 15° NOSE DEPRESSION

FIGURE D-9

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/3/76 Chamber No. 2

Project ______ Frequency 1636 MC Pattern Number 12

0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ______ Scale & Model ______

Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks:

CIRCULAR POL. 45° NOSE DEPRESSION

FIGURE D-11

IBM CORPORATION
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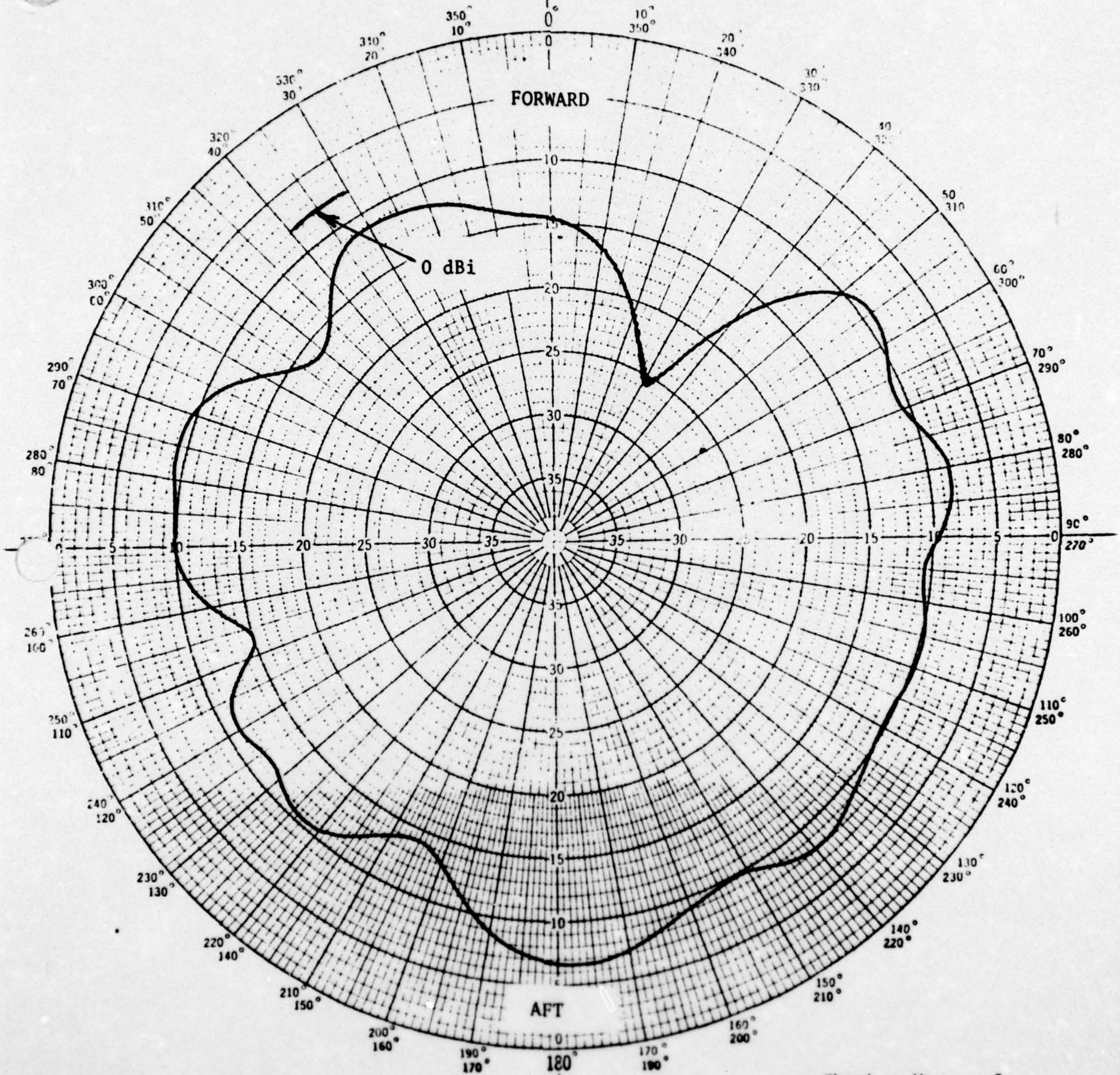
ANTENNA APPLICATIONS LABORATORY



Date 8/3/76 Chamber No. 2

Project ______ Frequency 1636 MC Pattern Number 13

0 dB Gain Chart Level ______ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____

Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____

Test Sample ______ Scale & Model ______

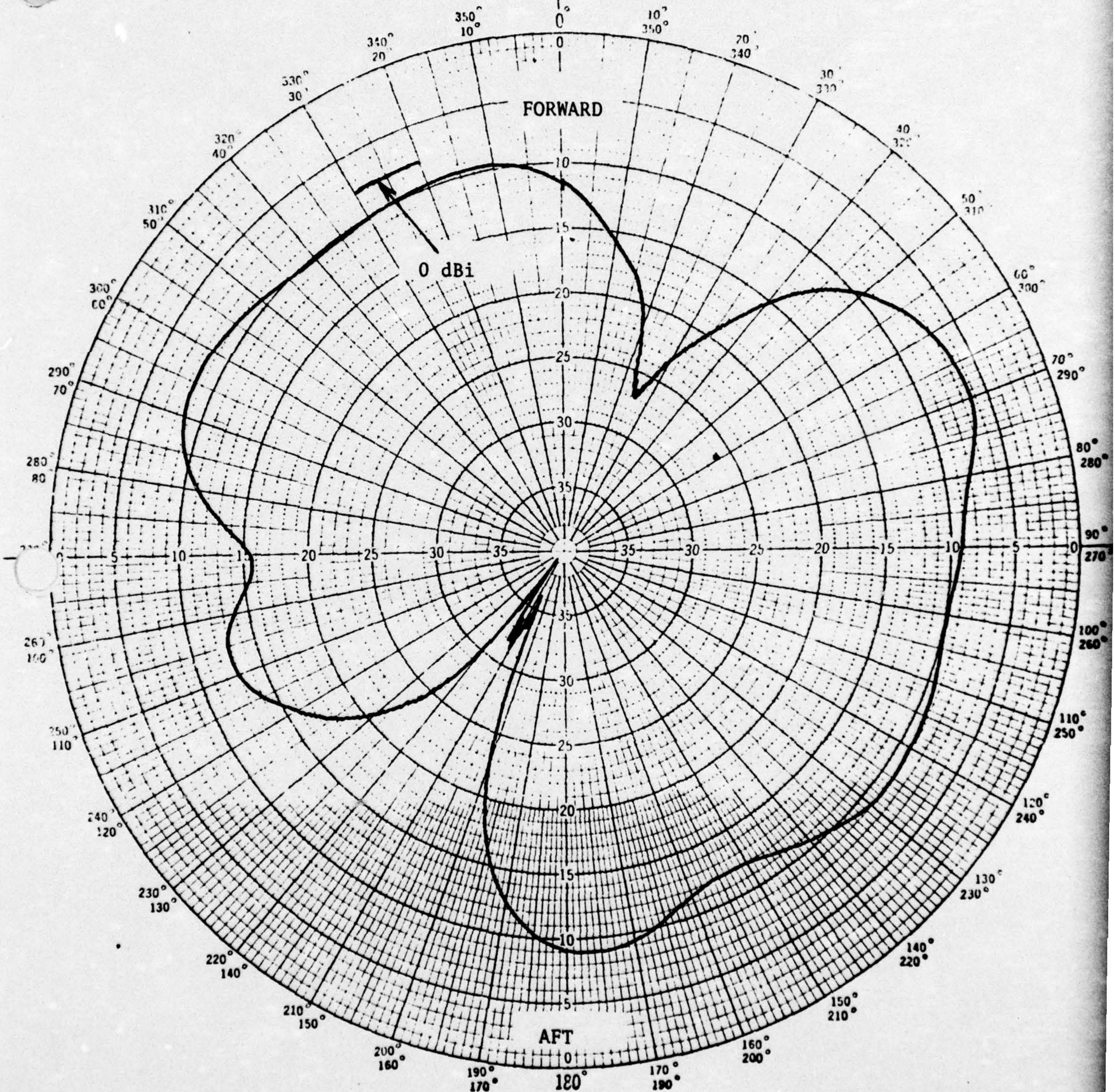
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____

Remarks:

CIRCULAR POL. 60° NOSE DEPRESSION

FIGURE D-12

IBM CORPORATION
ELECTRONIC SYSTEMS CENTER
ANTENNA APPLICATIONS LABORATORY



Date 8/3/76 Chamber No. 2
Project ____ Frequency 1636 MC Pattern Number 14
0 dB Gain Chart Level ____ dB, Curves Plotted in: Voltage ____ Linear (dB) ____ Power ____
Transmitter Polarization: Vertical ____ Horizontal ____ Rotating Linear ____ Circular ____
Test Sample ____ Scale & Model ____
Test Sample Polarization: Vertical ____ Horizontal ____ Circular (L-H) ____ (R-H) ____
Remarks: CIRCULAR POL. 75° NOSE DEPRESSION

FIGURE D-13

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